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APPLIED MECHANICS REVIEWS

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THEORY OF GAMES OF STRATEGY

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INTRODUCTION

In many economic, military, and operations research problems, the game factor dominates—i.e., the outcome or result can only be described in terms of the decisions made by several participants, each having a different objective. The theory of games, a relatively new branch of mathematics, analyzes such strategic problems by studying the following theoretical model patterned on actual parlor games such as chess and poker: A participant knows that one of several possible events will occur, and with respect to these events he has certain preferences. He lacks full control over the variables which determine the event. Although he has some control, other participants, who have different objectives, also influence the event. Further, the event may be influenced by random elements.

Games of chance have been studied mathematically for many years, and the mathematical theory of probability was developed from their study. Although strategic situations have long been observed and recorded, the first attempt to abstract them into a mathematical theory of strategy was made in 1921 by Emile Borel. The theory was firmly established by John von Neumann in 1928 when he proved the minimax theorem. However, it was the publication in 1944 of the impressive work "Theory of games and economic behavior," by John von Neumann and Oskar Morgenstern, that stimulated research in the mathematical theory of games.

By a *game* is meant a set of rules which specify unambiguously the number of *players*, the *moves* that each player may or must make under all possible circumstances, the moves that are made for the players by chance, the amount of *information* available to the players, and the *payoff* to each player. Von Neumann has given a mathematically precise definition of a game by making use of the notion of partition of sets.

Although each game is initially described in terms of its moves and the amount of information available to the players, we can normalize the game by the introduction of the concept of a strategy. In the actual play of the game, each player, instead of making his decision at each move of the game, may formulate a complete plan for playing the game from beginning to end, for every situation that may arise. Such a plan is referred to as a *strategy*. It takes into account any information that may become available in the course of the play of the game. No freedom of action is lost through the use of a strategy, since a strategy specifies a player's actions in terms of the information that may be available in accordance with the rules of the game.

Every game can be described in terms of the sets of strategies of the players, where each strategy is a player's method of playing a given game from beginning to end. Every combination of strategies, one from each player, will determine an outcome of the game which is measured by a payoff to each player. Thus the game is determined by the number of players, their strategies, and their payoff functions. If a player has n different strategies, they may be identified by the numbers $1, 2, \ldots, n$.

The fundamental problem of the theory of games of strategy is the determination of optimal strategies for each player and to evaluate the amount each player can expect to receive. No satisfactory theory exists as yet which solves the problem for an arbitrary number of players. In general, the difficulties are both computational and conceptual. However, the fundamental case of two players with opposing interests is conceptually complete and much progress has been made on the technical problems.

1. GAMES WITH FINITE NUMBER OF STRATEGIES

The mathematical model for games with two players having strictly opposing interests is deceptively simple: Player I chooses a strategy, any one of the numbers $i = 1, 2, \ldots, m$, and Player II chooses a strategy, any one of the numbers $j = 1, 2, \ldots, n$, each choice being made without any knowledge of the other. The payoff to Player I is a function of the chosen strategies a_{ij}, while the payoff to Player II is $-a_{ij}$. The objective of Player I is to maximize a_{ij}, but he controls only the choice of i, while the objective of his opponent is to maximize $-a_{ij}$ and he controls the choice of j. What are the guiding principles which should determine the choices and what is the expected outcome of the game? We have assumed that the outcome can be measured quantitatively by a number and that the notion of expectation is applicable for this measurement.

Among Player I's strategies there exists some strategy such that he can obtain a payoff of at least $\max_i \min_j a_{ij}$. Player II has some strategy such that he pays no more than $\min_j \max_i a_{ij}$. For every matrix (a_{ij}), we have

$$\max_i \min_j a_{ij} \leq \min_j \max_i a_{ij}.$$

If the game is such that

$$\max_i \min_j a_{ij} = \min_j \max_i a_{ij} = v$$

then Player I has a strategy which yields him at least v, and

he can be kept from getting more than v by the second player. Thus in this case, there are *optimal* strategies i^* for the first player and j^* for the second player which have the following properties: (1) if Player I chooses i^*, then, no matter what Player II does, Player I will get at least v; (2) if Player II chooses j^*, then, no matter what Player I does, Player I will get at most v; and (3) if Player I were to announce in advance of the play that he plans to use strategy i^*, Player II could not take advantage of this information and thereby reduce Player I's payoff.

A necessary and sufficient condition that $\max_i \min_j a_{ij} = \min_j \max_i a_{ij}$ is that the payoff matrix (a_{ij}) have a saddle-point; i.e., that there exists an element of the matrix which is at the same time the minimum of its row and the maximum of its column.

If the payoff matrix (a_{ij}) is such that it contains no saddle-point, and hence neither player has an optimal strategy, it is necessary to generalize the notion of a strategy. A player, instead of choosing a single strategy, chooses a probability distribution over his set of strategies and the particular strategy for the play of the game is chosen by some chance device satisfying this probability distribution. Each probability distribution over the set of strategies is a *mixed strategy*. This randomization by a player protects him against choosing a strategy which would benefit his opponent. Of course, any strategy can be regarded as a mixed strategy. However, to evaluate the effect of a mixed strategy, the expected value of the effect of the strategies needs to be determined.

Let S_m and S_n be the sets of mixed strategies of Player I and Player II, respectively. Let $E(X, Y)$ be the expected payoff received by Player I if he uses mixed strategy X and Player II uses mixed strategy Y; then it turns out that in any game with a finite number of strategies

$$\max_{X \in S_m} \min_{Y \in S_n} E(X, Y) = \min_{Y \in S_n} \max_{X \in S_m} E(X, Y) = v.$$

This is the main theorem of finite games, and was first proved by von Neumann in 1928. It shows that both players have optimal mixed strategies, i.e., there exists a probability distribution for Player I which assures him a gain of at least v on the average, and there exists a probability distribution for Player II which insures him against a loss of more than v on the average.

2. SOLUTION OF FINITE GAMES

The sets of optimal strategies can be characterized geometrically as closed convex polyhedra. Thus to find all optimal strategies we need only determine the extreme points of the convex set. L. S. Shapley and R. N. Snow have shown that each extreme point is associated with some nonsingular square submatrix of the payoff matrix (a_{ij}). Thus every optimal strategy which is an extreme point can be obtained as the unique solution of a suitably chosen subsystem of linear equations.

There exist iterative procedures for approximating optimal mixed strategies. The two most common procedures are due to George W. Brown and John von Neumann. The Brown procedure is a method of fictitious play which bases future decisions on relevant past history. In the von Neumann procedure the steady-state solution of systems of differential equations corresponds to the optimal strategies of the game.

3. GAMES WITH INFINITE STRATEGIES

Although most parlor games require the evaluation of a finite number of strategies, many military and economic games have an infinite number of strategies. For example, in such games it is frequently required to choose an optimal percentage from an infinite number of percentages. In an infinite game, the two players choose strategies x and y from infinite sets S_1 and S_2. The payoff is the value of a function $M(x, y)$. By analogy with the finite games, if

$$\max_{x \in S_1} \min_{y \in S_2} M(x, y) < \min_{y \in S_2} \max_{x \in S_1} M(x, y)$$

then mixed strategies are required. They are defined as probability distributions F and G over S_1 and S_2. Now Player I's expectation is given by the double integral

$$E(F, G) = \iint M(x, y)\, dF(x)\, dG(y).$$

The existence of optimal mixed strategies, i.e.

$$\max_F \min_G E(F, G) = \min_G \max_F E(F, G)$$

now depends on the function $M(x, y)$. If $M(x, y)$ is continuous with S_1 and S_2 unit intervals $0 \le x \le 1$, $0 \le y \le 1$, then optimal mixed strategies exist. However, if $M(x, y)$ is discontinuous, optimal strategies need not exist. Even when optimal strategies exist, as in the case of continuous $M(x, y)$, no general method exists for computing them.

The method of solution of infinite games depends upon the functional form of $M(x, y)$. In many applications the payoff function $M(x, y)$ is strictly convex in y for each x, in which case an optimal strategy for Player II is to choose that y which minimizes $\max_x M(x, y)$. However, Player I must use a mixed strategy generally consisting of two strategies. The value of the game is $\min_y \max_x M(x, y)$.

If the payoff function is a polynomial, i.e., if

$$M(x, y) = \sum_{i,j=0}^{m,n} a_{ij} x^i y^j,$$

then both players have optimal mixed strategies which are step functions. Each player randomizes on $\frac{1}{2}$ min $(m+2, n+2)$ strategies, at most.

4. EXAMPLES OF INFINITE GAMES

Allocation of Resources. The following attack-defense game has interpretations in economics as well as in military planning. Given n targets $T_1, T_2, \ldots, T_n$ whose values are $v_1, v_2, \ldots, v_n$, respectively. Suppose Player I has a total of A attacking units and Player II has a total of D defensive units. How should the players allocate their forces among the n targets? Let us assume that if $x = (x_1, x_2, \ldots, x_n)$, where each x_i is nonnegative and $\sum x_i = A$, is an allocation of Player I's resources among the n targets, and if $y = (y_1, y_2, \ldots, y_n)$ is an allocation of the defender's forces among the targets, then the payoff to Player I is defined by

$$M(x, y) = \sum_{i=1}^{n} v_i \max(0, x_i - y_i).$$

This is an $n-1$ dimensional infinite game with a continuous payoff and hence optimal strategies exist. If $A \ge D$, then the optimal strategy for the defender is to defend only the high-valued targets and leave low-valued targets undefended. However, the attacker must use a mixed strategy. He selects one of the targets at random, subject to a given probability distribution, and allocates his entire force A to that target. An interesting property of the optimal strategies is that the high-valued targets which are defended are also the targets which may, depending on the outcome of the randomization, receive the concentrated attack. The low-valued targets are undefended and never attacked. Further, the optimal strategies

and y^* are such that there exist no soft spots, i.e.,

$$v_i(A - y_i) = v = \text{constant}, \quad \text{if } y_i > 0$$
$$v_i A < v, \qquad y_i = 0.$$

Timing of Decisions. Many timing problems can be viewed two-player games whose rules describe the actions which players are to take, but the timing of the actions is to be termined by the players. In these games each player wishes delay the actions as long as possible but he is also penal- for delaying by his opponent. This conflict of interests be resolved and a best timing of actions can be determined each player.

Let us assume that each player has to choose only one ion time. Let us also assume that each player is informed his opponent's action as soon as it takes place. Define x) as the probability that Player I will succeed if he acts time x, and $P_2(y)$ as the probability that Player II will suc- d if he acts at time y. Let the payoff be +1 to the suc- sful player and 0 to both players if both or neither succeeds, n the expected payoff to Player I as a function of action es x and y becomes:

$$M(x, y) = \begin{cases} 2P_1(x) - 1 & \text{if } x < y \\ P_1(x) - P_2(x) & \text{if } x = y \\ 1 - 2P_2(y) & \text{if } x > y. \end{cases}$$

In this case the optimal action time for each player depends on the solution of the equation

$$P_1(t) + P_2(t) = 1.$$

Each player delays his action until t, if his opponent has not acted prior to t. If his opponent has acted prior to t, then the player acts at time x such that $P_i(x) = 1$, i.e., the player waits until he is certain of success.

If, in the preceding example, we remove the information aspect and assume that each player is ignorant of the action, if any, taken by his opponent, then optimal timing requires randomization by both players. Let us make the additional assumption that $P_1(x) = P_2(x)$, then the payoff function becomes

$$M(x, y) = \begin{cases} -y + (1 + y)x & \text{if } x < y \\ 0 & \text{if } x = y \\ -y + (1 - y)x & \text{if } x > y \end{cases}$$

where x and y are the probabilities of success of Player I and Player II, respectively. The two players have the same optimal strategies—delay until the probability of success is at least $\frac{1}{3}$, then act at a time chosen at random subject to the probability distribution

$$F(x) = 0 \qquad 0 \le x \le \tfrac{1}{3}$$
$$= \frac{1}{8}\left(9 - \frac{1}{x^2}\right) \qquad \tfrac{1}{3} \le x \le 1.$$

Bibliographic Notes

here exist several books on the theory of games of strategy as l as many articles in mathematical journals. Reference 3, below, ains a complete bibliography of books and articles.

ks on the theory of games include

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McKinsey, J. C. C., Introduction to the theory of games, New k, McGraw-Hill Book Co., Inc.

Kuhn, Harold W., and Tucker, Albert W., (eds.), Contributions to theory of games, I (1950), II (1953), Princeton Univ. Press. se two volumes contain a complete bibliography of game theory lications.

Blackwell, David, and Girshick, M. A., Theory of games and statistical decisions, New York, John Wiley and Sons, Inc., 1954; See AMR **7**, Rev. 3458.

For general reading, books on the theory of games include:

1 McDonald, John, Strategy in poker, business and war, New York, W. W. Norton and Co., 1950.

2 Williams, J. D., The Compleat Strategyst, New York, McGraw-Hill Book Co., Inc., 1954; See AMR **8**, Rev. 1260.

Basic technical papers include:

1 von Neumann, John "Zur Theorie der Gesellschaftsspiele," *Math. Ann.* **100**, 295–320, 1928.

2 Borel, Emile, and Ville, Jean, "Applications aux Jeux de Hasard," Traite Du Calcul Des Probabilites Et De Ses Applications, IV, pt 2, 1938.

"Letters to the Editor" and "Books Received for Review" appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 992, 993, 995, 1001, 1004, 1033, 1046, 1057, 1154, 1235)

Book—952. Bodewig, E., Matrix calculus, New York, Inter- ence Publishers, Inc.; Amsterdam, North-Holland Publishing mpany, 1956, xi + 334 pp. $7.50.

Volume treats theory of matrixes with applications to the solu- of linear equations systems and eigenvalue problems. The erical analysis side of the questions is also considered. The of the calculus is to employ the usual basic matrixes E_{ik} efine the elements of a matrix. The rows and columns are ted as vectors. The common representation of the elements is e used and the calculus permits a development based on ix operations. The book is divided into 4 parts. The first lops the basic theory of matrixes including bilinear and dratic forms, eigenvalues and vectors, bounds and extremum perties for the eigenvalues, etc. The theory of numerical edures and applications is reserved for the remaining ions of the tome. Part II treats the subject of linear equa- s. Part III is concerned with inversion of matrixes and part IV s with eigenvalue problems. Both direct and indirect (itera- methods are developed.

Book contains much valuable material and should prove useful to many applied workers. However, there are some criticisms and the reader should be on the lookout for certain defects. For example, author's criticism of the power method for computation of eigenvalues and vectors (pp. 250–254) is not fair, and his statement that the procedure is good only when the ratio of the largest to the next largest eigenvalue is greater than 3 is not true. This entire discussion is taken from a previously published article by the author ["A practical refutation of the iteration method for the algebraic eigenproblem"; AMR **8**, Rev. 2222]. It is not our purpose to answer the author's refutation completely here, but reader is referred to the article by J. H. Wilkinson ["Iterative methods for latent roots and vectors of matrices" *Math. Tables Aids Compt.* **9**, 184–191, 1955] where one is provided. One further comment is pertinent. Had the author applied the information on p. 249 to his example on p. 250, the difficulty would be apparent. This, together with a simple transformation on the eigenvalues, renders the iterative process efficient. The point is this: There is no panacea, and, to get results, methods must be used with some flexibility.

Throughout the volume, one finds historical remarks on certain formulas and theorems. This is useful and adds interest to the subject. One expects an historian to be logical, so much more so

a mathematician. On p. 189, there is a discussion of a formula which the author had previously attributed to I. Schur. The writer then lists various authors who have discovered it anew. Bodewig then writes "Later, I *heard* that the formula dates from Forbenius. A reference to literature was *not* given to me. But as the assertion is *probably true*, I will in future call it after both authors." (italics are reviewer's). On p. 244, in remarking on Aitken's delta-square process, author states that the process was first published 30 years earlier by Thiele, but no reference is presented. The book contains a list of references, but it is incomplete. In fact, author seems unaware of the extensive bibliography on the subject by G. E. Forsythe [AMR **7**, Rev. 2736]. Y. L. Luke, USA

953. Kron, G., Improved procedure for interconnecting piecewise solutions, *J. Franklin Inst.* **262,** 5, 385–392, Nov. 1956.

When a physical system, or its topological model, is torn apart into n independent parts, a factorized form of the true inverse matrix $\mathbf{Z}$ may be established by finding the inverse of $n + 1$ much smaller matrixes. No additional matrix multiplications are needed. The first n matrixes $\mathbf{Z}_1$ represent the n subdivisions, while the $(n + 1)$-th matrix $\mathbf{Z}_4$ represents a newly created physical system, to be called "intersection" system. The latter matrix is constructed out of the fragments of the inverted subdivisions. This paper shows that it is not necessary to establish the $\mathbf{Z}_2$ and $\mathbf{Z}_3$ matrixes that couple $\mathbf{Z}_4$ of the intersection system with $\mathbf{Z}_1$ of the n subdivisions. The role of the coupling matrixes can be taken over by the already established connection matrix $\mathbf{C}$. Thus the amount of storage and the clerical work are greatly decreased from that shown previously. Moreover, the number of multiplications needed to evaluate the unknown $\mathbf{E}$ for a given $\mathbf{I}$ is reduced. A simple numerical example is also worked out by the improved procedure. From author's summary

Book—954. Martin, W. T., and Reissner, E., Elementary differential equations, Cambridge, Mass., Addison-Wesley Publishing Co., Inc., 1956, xi + 260 pp. $5.50.

This is an introductory text for students in science and engineering, giving attention to setting up as well as to solving. Introductory chapter on setup is followed by chapters on first-order, second-order, higher-order, and equation systems, respectively, with consideration of singular points, series solutions, Laplace transforms, and other general methods of solution. Next, a chapter on approximate solution and Picard's theorem introduces the use of Taylor's theorem, quadrature formulas and iterations; these topics are strengthened by a brief chapter on finite difference equations. Finally, a short chapter on partial differential equations introduces the standard ones in their natural settings.

Numerous problems, with answers, are included.

A. S. Householder, USA

Book—955. Stepanow, W. W., Textbook of differential equations [Lehrbuch der Differentialgleichungen], Berlin, VEB Deutscher Verlag der Wissenschaften, 1956, ix + 470 pp.

This is a translation of the sixth edition of the excellent Russian text by the late W. Stepanow. It presents in thorough detail standard material for what might constitute a second-year graduate course in our universities, as it presupposes a certain maturity and acquaintance with analysis and more or less elementary algebra. The treatment of existence theorems is particularly extensive and there is a good introduction to the Lyapunov-Poincaré stability theory. Noteworthy also is an interesting historical chapter (the last). There are very many and varied problems with solutions given at the end of the book and it terminates with an ample bibliography.

S. Lefschetz, USA

Book—956. Sansone, G., and Conti, R., Nonlinear differential equations [Equazioni differenziali nonlineari], Rome, Consiglio Nazionale delle Ricerche, 1956, 641 pp.

This volume is the third one on the theory of differential equations. It deals with the theory of nonlinear differential equations, a subject which has attracted such widespread interest in recent years, particularly in view of its applications to the theory of oscillations.

Book deals with the qualitative theory of these differential equations; the quantitative methods of approximations by series are not included. It does not aim at applications directly but a great deal of its material relates to questions which arose in connection with the theory of oscillation and, thus, has a considerable interest for physicists and engineers who will find familiar topics presented from a mathematical point of view.

The text is based on the following fundamental subjects: analysis of isolated singular points of autonomous systems; existence of periodic solutions; asymptotic behavior of solutions and their stability. It is written in a clear and concise manner and is provided with a well-selected bibliography up to 1955.

Perhaps the best way of reviewing the contents of this important work is to give a brief account of its contents by chapters.

The book is divided into 9 chapters of which chapter I gives an introduction to the theory of differential equations in the real domain.

Chapter II concerns the theory of singular points which is of great interest in connection with the problems of equilibrium; some of its material goes beyond what is presently needed for applications but this is rather an advantage for those who are interested in establishing further contacts with physics, which are yet very limited. Chapter III may be regarded as a further extension of the preceding chapter and introduces the singularities of Briot and Bouquet, a more recent work of A. Wintner, and similar topics.

Chapter IV begins with an exposition of the general theory of characteristics, limit cycles indexes, and terminates with properties of the cylindrical and toroidal phase spaces which have acquired considerable importance in recent years in applied problems.

In chap. V the authors investigate the properties of autonomous systems and introduce some further generalizations due to H. Weyl, Keil and others; the end of this chapter concerns the question of structural stability.

Chapter VI is closely related to the theory of oscillations; it treats the autonomous differential equation, well-known in applications such as those of van der Pol, Liénard, and others. The following chap. VII relates to the nonautonomous systems with one degree of freedom; most of its contents relate to the recent work of Cartwright-Littlewood, Lefschetz, Levinson, Reuter, and others; it ends with the formulation of conditions for the existence of periodic solutions.

In chap. VIII are studied the linear systems, particularly those with periodic coefficients; it includes also Lyapounov's method of reduction as well as the theory of characteristic exponents. The last chapter gives a clear and condensed analysis of the various concepts of stability following Lyapounov and later results of numerous investigators, particularly those of the Russian school.

The book is strongly recommended to those who wish to acquire the fundamentals in this important field which is still in a rapid evolution as far as applications are concerned.

N. Minorsky, France

Book—957. Kantorovich, L. V., and Kriloff, V. I. Approximate methods of higher analysis [Naherungsmethoden der höheren Analysis], Berlin, Deutscher Verlag der Wissenschaften, 1956, 611 pp. 47 DM.

Originally published in Russian [AMR **5**, Rev. 970], this translation into German now makes this work readily available. The quality of the translation is excellent. W. A. Nash, USA

958. Latta, G. E., The solution of a class of integral equations, *J. rational Mech. Analysis* **5,** 5, 821-834, Sept. 1956.

A method is presented for reducing integral equations of first kind having the form $(*)g(x) = \int_a^b K(x-t)f(t)dt$ to ordinary linear differential equations when kernel $K(x)$ satisfies a linear differential equation of first degree (but any order). Such equations arise, e.g., when some boundary-value problems are handled by separation of variables. Method is illustrated by following examples: (1) $K(x) = \log|x|$, a, b finite; (2) $K(x) = K_0(|x|)$ (the modified Bessel function of the second kind), $a = 0$, $b = \infty$; (3) $K(x) = K_0(|x|)$, a, b finite. The first two examples are solved completely; the third is recuced to a pair of (nonelementary) differential equations containing parameters. Paper represents an interesting attack on an extremely difficult problem, but since the first two examples can be solved by other means and since it is not at all clear how much work is involved (reviewer suspects it is a great deal) in reducing differential equations obtained to some sort of final answer, one wishes for a completely worked out nontrivial example not otherwise soluble.

This is a rewritten version of author's earlier work ["The solution of a class of integral equations reducible to ordinary differential equations," Stanford Univ., Appl. Math. Stat. Lab. Tech. Rep. 32, Jan, 1955], in which it is mentioned that method is applicable to more general equations than (*).

M. Shinbrot, USA

Book—959. Bennett, A. A., Milne, W. E., and Bateman, H., Numerical integration of differential equations, New York, Dover Publications, Inc., 1956, 108 pp. $1.35 (paperbound).

Book is a reprint of monograph prepared for the National Research Council in 1931. Topics covered are: interpolation polynomial, successive approximation, step-by-step integration of ordinary differential equations, and methods for partial differential equations.

Only two of the four chapters—those dealing with the interpolation polynomial and with step-by-step integration methods for ordinary differential equations—contain material of immediate use to those interested in applications. Finite difference methods for dealing with partial differential equations are not discussed.

Main emphasis is on history of the subject. Footnotes tend to crowd main discussion off the page. Enormous bibliographies have been included with each chapter. Book is more of a guide for the historical researcher than a manual for the practical man.

A. W. Gessner, USA

Book—960. Nielsen, K. L., Methods in numerical analysis, New York, The Macmillan Company, 1956, xiii + 382 pp. $6.90.

Author has aimed to fulfill the need for an elementary textbook in numerical analysis for engineers. It is written assuming an automatic desk calculator to be at the reader's disposal, and its scope is wide. After two introductory chapters on rounding off numbers, machines, mathematical tables and finite differences, there follows one on methods of interpolation. Chapter 4 on differentiation and integration discusses all the classical formulas and includes sections on maxima and minima and numerical double integration. Chapter 5 is on the use of Lagrangian formulas for interpolation, differentiation, and integration. Chapter 6 is on the numerical determination of roots of equations and the solution of systems of equation, both linear and nonlinear. Crout's method of evaluating determinants is here described. Chapter 7 is an introduction to the integration of differential and difference equations. Chapters 8 and 9 are concerned with data fitting; chap. 8 discusses the application of least squares and describes the Neilson-Goldstein method. Chapter 9 is on harmonic analysis and include a section on autocorrelation functions. Tables of the various coefficients referred to through the book are appended, together with an extensive bibliography.

In reviewer's opinion, the outstanding feature of the book is the abundance of worked examples, all excellently set out and easy to follow. Furthermore, the methods described, both classical and more recent, are all efficiently adapted for working on a modern desk machine. Reviewer would like to have seen more emphasis laid on checking, especially in the earlier chapters; the minimum recording of data is recommended and sometimes the procedures suggested involve transfer of numbers by hand between registers without recording. Chapter 7 seems hardly adequate even as an introduction to the subject. Relaxation is only briefly discussed. Euler's inaccurate method, on the other hand, hardly seems to warrant inclusion. But these are criticisms of detail. Reviewer's main impression is that the author has produced an up-to-date textbook which can be well recommended as a basis for courses to engineers (and others) and also as a source of reference.

R. P. Pearce, Scotland

961. Schroder, J., New error estimations in different iteration methods (in German), *ZAMM* **36,** 5/6, 168-181, May/June 1956.

Error estimates are obtained for abstract iteration procedures, using methods of functional analysis. These are applied to systems of algebraic equations, both linear and nonlinear, and to systems of ordinary differential equations, with either one-point or two-point boundary conditions. W. Mersman, USA

962. Duleau, J., Numerical solution of certain linear equation systems (in French), *C. R. Acad. Sci. Paris* **242,** 7, 870-873, Feb. 1956.

963. Flemming, D. P., An iterative method for Taylor expansion of rational functions, and applications, *Math. Tables Aids Compt.* **10,** 55, 120-130, July 1956.

Title gives summary of paper. Application is made to inversion of Laplace transform of a rational function. Truncation and round off errors are studied. Y. L. Luke, USA

964. Kuntzmann, J., Remarks on the Runga-Kutta method (in French), *C. R. Acad. Sci. Paris* **242,** 18, 2221-2223, Apr. 1956.

965. Miller, G. F., A note on the numerical solution of certain non-linear integral equations, *Proc. roy. Soc. Lond.* (*A*) **236,** 1207, 529-534, Sept. 1956.

Methods are described for the numerical solution of two non-linear integral equations occurring in a hydrodynamical problem. In each case the existence of an essential singularity of the solution requires the application of special techniques. The asymptotic form of the solutions for large x is determined.

From author's summary

966. Kennedy, P. A., and Kent, G., Electrolytic tank, design and applications, *Rev. sci. Instrum.* **27,** 11, 916-927, Nov. 1956.

The theory of the electrolytic tank analog as a device for the solution of potential problems is reviewed and applications to network problems, magnetic field plotting, and electron optics concisely discussed.

The desirable mechanical requirements of an electrolytic tank design are stated; a description of the new Harvard tank indicates how these features are obtained; and the experimental accuracy is remarked (the figure of mechanical uncertainty for the Harvard tank is estimated to be 0.01 in.).

Discussion covers experimental error in tank measurements due to electric circuit effects, problems of electrode and electrolyte materials, and probe effects due to surface tension.

Control experiments for determining the accuracy of level and tilted tank measurements are described, and the results presented. High accuracy is possible in the level tank, but great care is needed in the tilted tank to obtain results reliable to within 3%.

Readers interested in this paper will find much pertinent material in reviewer's exhaustive account of literature of electroanalogic

methods: see AMR **9**, Jan. & Feb. Feature Articles and AMR **10**, Feb. Feature Article. T. J. Higgins, USA

967. Mazelsky, B., and O'Connell, R. F., The integrated use of analog and digital computing machines for aircraft dynamic load problems, *J. aero. Sci.* **23**, 8, 721–740, 780, Aug. 1956.

Authors review application of analog and digital techniques to solution of problems in vibration, flutter, gust loads, taxi and landing loads so as to provide maximum information in a minimum of machine time. It is shown how each of these problems can best be studied during either the preliminary design, or shake test, or final analysis, development period of the aircraft. Advantages and disadvantages of both analog and digital computers are discussed for each application. It is concluded that an integrated approach employing both types of computer, and utilizing finite difference approximations, is most satisfactory. Authors admit that over-all cost of such an approach may be a drawback, but suggest that this may well be offset by desirability of obtaining more rational design requirements.

Details are given of application of method to tail symmetric flutter analysis of a current transport-type aircraft.

S. Kirkby, England

968. Barker, J. R., Applications of a transformer analogue computer, *Brit. J. appl. Phys.* **7**, 8, 303–307, Aug. 1956.

The Blackburn-type transformer analogue computer at Imperial College of Science and Technology (London), originally conceived of as an a-c network analyzer, is shown to be useful in the solution of a variety of algebraic problems (systems of linear and nonlinear equations, matrix inversion, solution of polynomial equations, etc.). Its utility is enhanced by the ease of representing complex quantities by their real and imaginary parts, and by performing complex multiplication (and division) by a pair of transformers. Systems of linear algebraic equations are the simplest to handle, the constants being set in as turns ratios and the solutions read off by voltmeters. In the case of polynomial equations, it is necessary to search for the roots by varying transformer turns-ratios (for each transformer this is done by means of decade switches), a rather tedious process. Limited amount of equipment in Imperial College installation restricts linear systems to 5 equations in 5 unknowns. Accuracy as good as 1 part in 500 is obtainable in favorable cases, but quoted results indicate something like 1 part in 100.

Since the Mallock linear equation solver using transformers (though in a different way) is well known, and since a variety of network calculators have been used for the solution of algebraic problems, reviewer's opinion is that nothing essentially new or unexpected is contained in this paper.

C. V. L. Smith, USA

969. Gurov, V. V., Kogan, B. Y., Talantsev, A. D., and Trapeznikov, V. A., A new electronic simulation apparatus of the Institute of Automation and Remote Control of the USSR academy of sciences, *Automation and remote control* **17**, 1, 15–29, Jan. 1956. (Consultants' Bur. Translation)

A brief description is made of a new small electronic simulating apparatus ESU-5, which was developed in 1954. Paper examines the action of the decision amplifiers, which operate with an economical output stage and nonlinear blocks with potential-grounded diodes. It describes the new circuits for the multiplying-dividing system, the establishment of the initial conditions, the transfer coefficients of the blocks, and the overload indications.

From authors' summary

970. Sattinger, I. J., Scope "visualizes" computer results, *Control Engng.* **3**, 10, 109–113, Oct. 1956.

It is difficult to "see" what goes on in a simulated physical system from the abstract presentation of a multichannel recorder. The system described in this paper paints a dynamic picture of the mechanics on an oscilloscope. This helps the engineer find the optimum simulator settings more quickly, and provides a graphic demonstration of the results of his work for others.

From author's summary

The following seven papers 971–977 on interpretation of empirical data appeared in the Proceedings of a colloquium held at Luxembourg in July 1953 during the Congress of L'Association Francaise pour L'Avancement des Sciences. These Proceedings appeared in French in Publ. sci. tech. Min. Air, France *NT 52, 77 pp., 1955.*

In the preface, M. P. Vernotte stresses the importance of this problem to all experimentalists.

971. Arend, S., Interpolation and extrapolation based on the method of least squares, pp. 1–8.

Author shows how modified matrix methods lead easily, by least squares, to the determination of the Lagrange polynomial for interpolation and extrapolation of experimental data, and to the calculation of least residuals according to this criterion. It is assumed that successive values of the independent variable are equidistant. The processes do not require the calculation of differences but permit continuous checking of the calculations by the use of row sums. S. Kirkby, England

972. Dommanget, J., Determination of the parameters of the function $y = a + bf(x,\alpha,\beta,\ldots)$, pp. 9–28.

Author derives practical procedures, based on least squares, for evaluating the parameters of the title function. Calculation of the most probable values of the parameters is divided into two stages: the evaluation first of $\alpha, \beta, \ldots$, and secondly of a and b. There is direct analogy with statistical methods for standard deviation, Pearsonian correlation coefficient, and regression analysis. The exponential law $y = a + b \exp(\alpha x)$ is considered separately, and an example to determine the regression of y on x, and x on y, is included.

S. Kirkby, England

973. Dommanget, J., Study of the laws characterising either a functional relation, or statistical dependence, between two variables, pp. 29–39.

This is a theoretical study of the determination, by least squares, of a linear relationship between two variables for the cases in which one of the variables is, or is not, known exactly and according as the dependence between them is denoted by a relation or a correlation. For a relation, the experimental errors are represented by the mean error; for a correlation, by their dispersion.

S. Kirkby, England

974. Schmitt, A., Determination of the homographic function from numerous experimental data with equally spaced abscissae, pp. 41–53.

A procedure is described for the representation of n given experimental points by the homographic function $(x + a)(y + b) = c$, and for the successive evaluation of a, b, and c. The cases n even and odd are considered separately and a criterion given for homographic representation. Since this procedure does not employ the method of least squares we have, here and in the second paper, two different methods for estimating the constants of the homographic representation.

S. Kirkby, England

975. Schmitt, A., Representation of a set of experimental points by a function of the form $y = a + b \exp(\alpha x)$, pp. 55–59.

The ordinates are partitioned appropriately into groups of three and two for the evaluation of α and b, respectively, whence a follows from the sum of ordinates. Again the

procedure is independent of the method of least squares and is alternative to the method of the second paper.

S. Kirkby, England

976. Ziller, A., **Numerical integration, between 0 and 1, of the second order parametric equation $y'' + \lambda (2 - x^2) y = 0$, with boundary conditions $y(0) = 0$, $2y(1) = 0$,** pp. 61–66.

This equation arises in the problem of a nonhomogeneous vibrating chord, fixed rigidly at one end, and elastically at the other. Author employs transformation $y(x) = xz(x)$ and then evaluates derivatives of z at $x = 0$ in terms of the parameter λ for substitution in the Taylor series for z and z' around $x = 0$. These series are truncated, arbitrarily, at the eleventh order terms and substituted in the transformed boundary condition to yield a polynomial equation with rapidly decreasing coefficients from which λ can be evaluated. Back substitution permits y to be expressed as a series of (odd) powers of x.

S. Kirkby, England

977. Vernotte, P., **The real problem,** pp. 67–77.

The thesis expounded is that when a curve is fitted to a set of experimental results it is not necessarily the curve itself which is required but some parameter associated with the experimental results. However, while the method of least squares can yield the best curve, it does not necessarily give the best value of a parameter, particularly in those cases where the curve is of a function of several parameters.

S. Kirkby, England

978. Ergun, S., **Application of the principle of least squares to families of straight lines,** *Indust. Engng. Chem.* **48**, 11, 2063–2068, Nov. 1956.

979. Russell, A. M., **Statistical approach to spatial measurement,** *Amer. J. Phys.* **24**, 8, 562–567, Nov. 1956.

A method of determining length is described which reduces the measurement to a counting operation. The same technique is then applied to the measurement of flat areas and sections of the surface of a sphere. The limits of error are discussed, and in particular the dependence of the error upon shape, and the choice of a lattice is observed in the measurement of flat areas. Some possible applications are suggested.

From author's summary

980. Junkes, J., **Suggested empirical reduction of spectral distributions** (in German), *Pont. Acad. Sci. Scripta Varia* no. 11, 239 pp., 1952.

In the past, no completely satisfactory method has been available for the comparison of two or more distributions of spectral frequencies. A method is developed in this paper which treats this problem from the viewpoint of matrix solution and uses statistical methods for a quantitative comparison.

The methods, as set forth by the author, represent a significant contribution in the data-handling and spectrographic analyses. The linear regressions used, however, could be augmented by more work in the area of multiple regression surface fittings.

Convenient separation is made between the theoretical portion and the practical portion of the work so that these newer methods are more readily available to the practicing scientist.

J. H. Davidson, USA

981. Kahn, H., **Applications of Monte Carlo,** U. S. Air Force Project RAND, (RM-1237-AEC), 250 pp., Apr. 1956.

In addition to its $10 table of a million random digits, Rand Corporation publishes verbal assistance to users of the Monte Carlo method. Part of this 250-page memorandum shows how to generate 27 different probability density functions, ranging from $2 - 2x$, $6(x - x^2)$, nx^{n-1}, through Gaussian and Poisson distributions to the Klein-Nishina scattering function, e.g., a Poisson distribution with mean and variance a can be generated by recording the number of multiplications of successive random numbers on the unit interval required to yield a product less than $\exp(-a)$, where a zero is recorded whenever a random number is itself less than $\exp(-a)$. This method is useful because only one comparison number is necessary. Other helpful concepts for Monte Carlo methods users are scattered throughout the paper, including discussions of the economics of sampling and appendixes devoted to pseudo-random number generation and the constrained maximum of a function.

Although a high tone of the paper is set by the co-sponsoring groups, the Atomic Energy Commission and the U. S. Air Force, reviewer has found uses for its basic ideas on such mundane subjects as high-speed textile machinery and machine-tool control equipment.

E. C. Varnum, USA

982. Slade, J. J., Jr., **Some observations on formal models for programming,** *Trans. ASME* **78**, 1, 47–53, Jan. 1956.

Paper modifies the usual linear assumptions of programming in order to account for saturation effects. This is done by using a profit function which is dominated by a linear term for small rates of production and by a negative exponential term for high rates of production. The mathematical development of the solution to this nonlinear program is given in the appendix of the article. The solution is stated in the article and an example is computed to illustrate it.

Reviewer believes that this is a useful approach to dealing with a likely type of nonlinearity. Paper is strictly formal, but indication is given that author's method can be adopted for application.

M. Shubik, USA

983. Helfenstein, H. G., **Graphical determination of a discontinuity surface by wave deflection,** *Quart. appl. Math.* **14**, 1, 93–97, Apr. 1956.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 1024, 1180, 1184)

Book—984. Timoshenko, S., and Young, D. H., Engineering mechanics, 4th ed., New York, McGraw-Hill Book Co., Inc., 1956, x + 478 pp. + appendixes. $7.50.

Book is divided about equally between statics and dynamics. The portion dealing with statics contains the familiar chapters on force composition and resolution for the various classifications of force systems, both in a plane and in space. In addition, a chapter on the method of virtual work, which seems to be gaining popularity in the newer books, is included. The part having to do with dynamics considers particle and rigid body motion in a plane only.

The organization of the material on dynamics is arranged differently from most other books on the subject in that the chapters are divided according to the kind of motion which the body is undergoing, rather than according to the type of analysis used in solving the problem. There are separate chapters on rectilinear translation, curvilinear translation, rotation about a fixed axis, plane motion, and relative motion.

In each of these chapters, authors first develop the necessary kinematic relations; next they apply Newton's second law; and finally they apply the integral principles of work and energy, and impulse and momentum. This organization is not preferred by the reviewer; however, to the student it may offer no particular difficulties.

The figures and free body diagrams accompanying the explanatory text material are excellent. The text material itself is also very well presented, and is written at the student's level. Many examples are included to help the student make the transition between the general theory of the text and the problems he must solve.

The variety of excellent problems in each chapter, half with answers given, have a wide range of difficulty.

H. J. Plass, Jr., USA

Book—985. Loitsianskii, L. F., and Lur'e, A. I., A course in theoretical mechanics, I. Statics and kinematics, II. Dynamics [Kurs teoreticheskoi mekhaniki. I. Statika i kinematika; II. Dinamika], 5th ed., Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1954, 379 pp.; 1955, 595 pp.

The fourth edition of this work on mechanics has been reviewed in AMR **6**, Revs. 3300, 3301. The present edition is largely revised and differs in many respects from the previous ones.

Some topics explained in other courses and material which usually is not covered in the first two courses on theoretical mechanics are now included.

Examples illustrating theory are discussed throughout the text, including many solved problems.

V. Vodicka, Czechoslovakia

986. Carter, W. J., Kinematic analysis and synthesis using collineation-axis equations, ASME Fall Meet., Denver, Colo., Sept. 1956. Pap. 56-F-4, 7 pp.

Using the line joining the two instant centers of a four-bar linkage as a reference axis, author shows that the angular accelerations of the cranks and connecting link can be determined directly by extending the work of Koenig and Freudenstein [AMR **9**, Rev. 2817]. A semigraphical method is suggested for the design of a four-bar linkage which satisfies the given ratio of the angular velocity of the driven crank to the angular velocity of the driving crank and its higher derivatives.

By employing Taylor's expansion to express the functional relationship between the positions of the driving and driven cranks, author claims that the "equivalence of the time and displacement derivatives" of the cranks are shown. Reviewer considers that this statement is misleading because such an "equivalence" can be easily shown to exist only when the velocity of the driving crank is constant. In view of this fact, the aforementioned graphical method should be modified accordingly to achieve author's claimed purpose. L-W. Hu, USA

987. Prussak, H., The influence of external forces on the position of the frictional center (in German), *Dtsch. Eisenbahn Tech.* **4**, 6, 233-238, June 1956.

Author recalls that, according to previous work done by Uebelacker, the slipping of the wheels of a carriage rolling on a railway can be considered as a movement of rotation round a point which was called frictional center.

When no external forces act on the carriage, this center lies at the intersection of the longitudinal axes of the carriage with the principal radius (a straight line going through the center of curvature of the track curve and normal to the longitudinal axis). This frictional center shifts on the principal radius when external forces are applied. This shifting e is calculated for two cases: (a) when the two wheels of a shaft are differently loaded; (b) when a longitudinal force Z is applied.

As the equations are of a high degree, diagrams are given for practical application. D. DeMeulemeester, Belgium

988. Jones, L. M., Transit-time accelerometer, *Rev. sci. Instrum.* **27**, 6, 374-377, June 1956.

An omnidirectional transit-time accelerometer, developed for measuring the drag acceleration of spheres dropped from rockets, is described. The ambient density and temperature of air may be calculated from the drag acceleration. In the device, a bobbin is periodically caged and released within a cavity. The time for the bobbin to traverse the distance to the cavity, which distance is the same in any direction, is telemetered and measured. The accelerometer range is about 5×10^{-3} to 5 g. Systematic errors and standard deviations over the range are about 1%. The accelerometer was used successfully in a rocket flight in which the drag acceleration of a 7-in. diam sphere was measured.

From author's summary

989. Linn, S. S., and Wenig, H. G., Centrifugal pendulum, *Prod. Engng.* **27**, 7, 164-166, July 1956.

Paper derives formulas for torque, energy, and time to swing. A sample calculation illustrates their application.

From authors' summary

990. Jones, J. H., and Horonjeff, R., Determination of radii of curvature of taxiways, *Trans. Amer. Soc. civ. Engrs.* **120**, 27-34, 1955.

991. Worley, W. S., Designing adjustable-speed v-belt drives for farm implements, *SAE Trans.* **63**, 321-333, 1955.

Servomechanisms, Governors, Gyroscopics

(See also Revs. 969, 1189, 1192)

992. Kavanagh, R. J., The application of matrix methods to multi-variable control systems, *J. Franklin Inst.* **262**, 5, 349-367, Nov. 1956.

Statement of Problem: Extension of standard linear control engineering to the case of several inputs and outputs. Synthesis of a multivariable feedback loop that fits the given plant.

Description of Method: Use of straightforward matrix analysis.

Statement of important results: Generally one finds $m\,n$ linear equations for $n^2 + mn$ unknowns. Supplementary constraints are added in order to more closely fit the actual problem. Two realizability criteria are stated that allow one to find whether the system is compatible or not. In order to use Laplace operator S, one tentatively replaces S by a real number.

Critical comment: According to reviewer's knowledge, such a systematical matrix approach control systems had not been previously published. "Scattering matrixes" are in use for microwave networks. Reviewer finds, instead of (11) (p. 352), $H' = HC(1 - HK)^{-1}$. Anyway (12) is true, obtained directly by use of (10) and (8).

This paper can be considered as just the beginning of a very important work, whose cornerstone should be some "Nyquist" analysis of stability. J. M. Loeb, France

993. Doetsch, G., Stability investigations of automatic control systems with aid of Laplace transformation (in German), *Öst. Ing.-Arch.* **10**, 2/3, 140-148, 1956.

For stability investigations, the singularities must be considered not only in the finite part of the s-plane, but also in the infinity. As an example a function is shown which gives unstable oscillations with increasing amplitude, having no finite singularities. Special theorems are derived to relate the asymptotic behavior of the original function with the configuration of the singularities of the Laplace transform. These theorems are also important for control systems with dead time.

W. Oppelt, Germany

994. Gollin, N. W., Cascade control systems, *Control. Engng.* **3**, 7, 94-98, July 1956.

The problem involved is to improve the performance of a regulator in process control (stripping column and jacketed kettle simply quoted as examples). The method used is a linear technique. The method employs a multiple loop: one of the links is itself a feedback loop. The transfer function of this link partially is compensated by the feedback action. It is found that the natural frequency is increased, whence a faster response to mid-loop disturbances.

All the principles and formulas of this paper are known, and can be found in the books quoted as references.

Reviewer believes that the interest for a control engineer would have been considerably increased, had the paper left the domain of general theory in favor of actual problem, giving practical figures and recordings of performances.

J. M. Loeb, USA

995. Nightingale, J. M., Analyzing servo systems, *Mach.*

Design **28**, 22, 87–91, Nov. 1956.

Two examples—a position control system and an engine governing system—show how transient response criteria are employed to determine performance. From author's summary

Book—996. Schultz, M. A., Control of nuclear reactors and power plants (McGraw-Hill Series in Nuclear Engineering), New York, McGraw-Hill Book Co., Inc., 1955, viii + 313 pp. $7.50.

This book is written for the engineer who is responsible for or interested in the design of nuclear reactor control systems. Naturally it is assumed that the reader has an acquaintance with the elementary physical processes unique to nuclear reactors. Chapters one through six of Glasstone's "Principles of nuclear reactor engineering" (D. Van Nostrand Company, New York, 1955) would serve as an excellent introduction to Schultz's book. Since the book is intended for those interested in control, a background in control and servo concepts such as transfer functions, frequency responses, and block diagrams is necessary. The chapters on Reactor control mechanisms (5), Reactor control radiation detectors (7), and Operational control problems: Startup (8), and Shutdown (10) could be read without knowledge of servo design techniques if one wanted an introduction to reactor control.

The book very properly deals with the two broad aspects of nuclear reactor control. In the first part, the behavior of the reactor itself, including internal temperature and fission product poison feedback, is developed in considerable detail without getting bogged down in the details of the nuclear physics design. In general, the reactor is treated as a black box and the necessary descriptive transfer functions are developed in a very straightforward manner. The control of the reactor is then considered from the point of view of providing automatic control. A discussion of the mechanisms used to drive control rods is also included.

The second part of the book deals with the very important problem of the interaction of a power reactor with the power generating equipment, including boilers, turbines, etc. The dynamics of the power-plant components are developed in servo-terminology and format so as to allow these powerful techniques to be applied to an entire system. The book concludes with an excellent chapter on reactor and associated power-plant component simulators.

The book is well written, includes many diagrams, calculated results, and approximately 65 problems. This is an engineer's book. With it, the engineer can gain a great deal of insight into the problems of nuclear reactor design, control, and operation.

R. S. Wick, USA

997. Janssen, J. M. L., A practical guide to plant controllability, *Control Engng.* **2**, 11, 58–63, Nov. 1955.

Article refers to continuous-process-type plant with automatic feedback control. Controllability is studied in terms of the ratio of response to a disturbance first with, and then without, controller in operation. Importance of high resonant frequency is demonstrated, and factors which affect this are studied. Examples are given for typical plants having different transfer functions.

C. D. Pengelley, USA

998. Weick, F. E., and Abramson, H. N., Investigation of lateral control near the stall. Flight tests with high-wing and low-wing monoplanes of various configurations, *NACA TN* 3676, 34 pp., June 1956.

Flight tests were made with typical light airplanes to investigate possibilities for obtaining reliable lateral control at low flight speeds. Maximum angle of attack below the stall at which control is still available were determined for each airplane, as well as elevator deflection required to trim at this condition, with power off and on, and to make a three-point landing. One airplane was tested with different horizontal tail configurations in an attempt to provide an arrangement that would give near-optimum conditions with regard to the effect of power change on longitudinal trim near the stall.

From authors' summary by W. S. Aiken, Jr., USA

999. Weick, F. E., and Abramson, H. N., Investigation of lateral control near the stall. Analysis for required longitudinal trim characteristics and discussion of design variables, *NACA TN* 3677, 91 pp., June 1956.

Analytical design procedures for estimating elevator deflection required to trim in steady longitudinal flight are presented. Pertinent data and formulas for use in evaluating longitudinal trim characteristics are summarized from existing literature. Two light airplanes are analyzed quantitatively to illustrate use of methods and provide comparison with flight-test results. Calculated values of elevator deflection for both airplanes are presented to demonstrate quantitative effects of changes in some of the more important design parameters.

From authors' summary by W. S. Aiken, Jr., USA

1000. Profos, P., Dynamics of pressure and combustion control in steam generators, *Sulzer tech. Rev.* **37**, 4, 1–15, 1955.

Paper reformulates the basic dynamics of pressure and combustion control for steam generators. The modern high-pressure steam generator is separated into components such as firing system, thermal inertia, storage, etc., and transfer functions for each component are derived. The analysis extends that of previous workers by including the effect of reheating. Four tables are included in the paper and show graphically and analytically the transfer functions.

As the analysis leads to equations of a high order, author suggests the use of analog computing devices.

Reviewer feels this paper should be in the hands of everyone concerned with problems of steam-generator control.

W. A. Wolfe, Canada

1001. Erugin, N. P., Methods for solving questions of stability in general (in Russian), Trans. Second all-union Congr. on the theory of automatic control. Vol. I, 133–141. Izdat. Akad. Nauk SSSR, Moscow-Leningrad, 1955.

A general lecture, after the manner of the symposium lectures of the American Mathematical Society, on the work done recently in the USSR on the topic under consideration. An extensive bibliography is given. S. Lefschetz, Mexico

Vibrations, Balancing

(See also Revs. 984, 1024, 1180)

Book—1002. Malkin, I. G., Some problems of the theory of nonlinear oscillations [Nekotorye zadaci teorii nelineinyh kilebanii], Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1956, 492 pp. 16 rubles.

This is a book written with a great deal of care by one of the outstanding Soviet masters of the subject. It stands somewhere between the text book (for fairly advanced students) level and the level for advanced specialists. Furthermore it addresses itself not only to the strict mathematician—to whom it has much to say—but also to the student of applied mathematics. Withal it never relaxes its mathematical vigilance. One of the distinguishing features is its detailed attention to methods of calculation. For instance in dealing with periodic solutions of resonant nonautonomous systems, 5 pages are devoted to the calculation of the solutions for analytic systems, 12 more for nonanalytic systems including a detailed proof of the convergence of the successive approximations which are used in this case. A number of detailed technical examples are discussed throughout. Noteworthy also is an extensive treatment—we believe the first in a treatise—of almost periodic oscillations. An objectionable feature, dictated perhaps by didacticism, is the failure to make an energetic use of vector-matrix notations with resulting complications that one may well guess. This is, however, a general failing in practically all the Soviet writings on differential equations. The absence of a bibliography is also to be noted, but there are abundant footnotes throughout the book.

Table of Contents. Chap. 1. Quasilinear oscillations with one

degree of freedom. Chap. 2. Periodic oscillations of quasilinear systems with many degrees of freedom. Chap. 3. Stability of oscillations. Chap. 4. Almost periodic oscillations of quasilinear systems. Chap. 5. Quasiharmonic systems: (a) Free oscillations; (b) Forced oscillations. Chap. 6. Systems near to arbitrary nonlinear systems. Chap. 7. Lyapunov systems. (Linear terms with at least one pair of pure complex characteristic roots.) Chap. 8. Systems near to Lyapunov systems. S. Lefschetz, USA

1003. Raskovic, D. P., On some characteristics of the frequency equation of small vibrations of holonomic conservative systems with static couplings, *Quart. appl. Math.* **14,** 3, 309–311 (Notes), Oct. 1956.

Paper treats the oscillations of a series of equal disks or masses connected by springs of equal constant. Boundary conditions considered are (a) end disks free of external torque, (b) shaft clamped at both ends, (c) one end as in (a) and the other as in (b). Recurrence formulas are obtained for the frequency equations and for the coefficients in these equations. Characteristic numbers are obtained for all three cases and substitution of these in the frequency equations yields closed expressions for certain finite trigonometric sums and products.

C. T. West, USA

1004. Woernle, H.-Th., A matrix method for beams with several sections—buckling and vibration (in German), *Stahlbau* **25,** 6, 140–145, June 1956.

Paper gives a survey on some recent work concerning the application of matrixes to vibration problems of beams. After an introduction, papers of Schnell [AMR **9,** Revs. 1060, 1771], Marguerre [AMR **9,** Rev. 3179], Fuhrke [AMR **9,** Revs. 1008, 3515], Falk and Pestel (these last two not yet reviewed in AMR) are briefly discussed; two examples are given comparing the methods of Fuhrke and Pestel particularly. K. Marguerre, Germany

1005. Ellington, J. P., The vibration of segmented beams, *Brit. J. appl. Phys.* **7,** 8, 299–303, Aug. 1956.

Pure bending vibrations of uniform beams are studied by replacing the continuous mass distribution of the beam by a number of concentrated masses spaced at equal distances. Frequency equations are given for various end conditions. For a sufficiently large number of segments these equations, of course, go over into the equations of the continuous beam.

There are two possibilities of replacing a continuous beam by a segmented one. The mass of each segment can either be placed at the center of the section, or one half of the mass can be placed at each end of the section. It is shown that, for a simply supported beam and for a beam built in at each end, both mass distributions underestimate the natural frequency of the actual beam, with the end mass giving the better approximation. With the free-free beam and the cantilever beam, however, the central mass distribution gives the more accurate estimate.

Paper throws some light on the question of errors inherent in the "lumped mass" approximation. H. Parkus, Austria

1006. Vandeghen, A., Alexandre, M., and Leloup, L., Critical speed of bending of turbine rotors. Practical determination by calculation and by measurement (in French), *Rev. univ. Min.* **99,** 1, 3–20, Jan. 1956.

Paper deals with the experience of the authors in the determination of the critical speed of rotor axes of large ship turbines. In the first part the possible error in the calculated critical speed, caused by the width of the supports, the mass of the adjacent coupled parts, the moment of inertia of the rotor disk, changes in cross section of the axis, and the variation of the modulus of elasticity with temperature, is considered and estimated. It is shown that the total error due to these influences is fairly constant for different types of turbines. This fact is used in a procedure which allows the calculation of the critical speed with a known safety margin.

The second part describes the equipment used for the experimental determination of the flexural natural frequency of rotor axes. The factors giving a difference between natural frequency and critical speed are considered. Finally, in the third part, the flexibility of the supports has been taken into account in the calculation of the critical speed. H. Bergh, Holland

1007. Piatek, M., Dynamical stability of axially loaded bars with arbitrarily variable cross sections (in Polish), *Arch. Mech. stos.* **8,** 1, 51–68, 1956.

The problem of dynamical stability of a bar on hinged supports loaded with a pulsating axial force is solved. It will be assumed that the distribution of load, the variability of the rigidity, and the cross-sectional area along the beam are arbitrary and can be expressed by means of Fourier series. The solution of the differential equation of vibration is assumed in a similar form. This equation is solved by orthogonalization, with the entire series assumed for the solution. The ordinary integrals thus obtained, treated as Radon's integrals, lead to the extremal problem of a certain function. Using the Hamilton-Ostrogradsky formula of the variational calculus, we obtain a system of differential equations determining the solution. These equations are, in the first approximation, of the Mathieu type. The corresponding Strutt maps are presented. For higher degrees of approximation we obtain systems of Hill's equations, represented here in the matrix form. Finally, a numerical example is treated in detail.

J. Naleszkiewicz, Poland

1008. Anliker, M., Flexural vibrations of twisted rods fixed at one end and simply supported at the other (in German), *ETH* Prom. no. 2539. 42 pp., 1955.

Author is concerned with computing the effect of initial twist of a slender rod on the frequencies of flexural vibrations. Two cases are considered; in each the rod is held vertically, with its lower end built-in. In the first case, the rod is simply supported at the upper end; in the second, it is free at the upper end but has a mass attached to it at this point. Author exhibits the frequency equation corresponding to each situation and discusses its approximate form for small angles of twist. Numerical results accompany the analysis. H. Deresiewicz, USA

1009. Dublin, M., and Friedrich, H. R., Forced responses of two elastic beams interconnected by spring-damper systems, *J. aero. Sci.* **23,** 9, 824–829, 887, Sept. 1956.

The method of this paper is very useful for the analysis of taxiing loads on seaplanes, which is the problem treated in detail, and also for finding bearing loads in a rotating system with several disks and elastically restrained bearings. It is an extension of the method originally developed by reviewer for finding bending vibration modes of single beams. However, this method has been simplified, and the large amount of algebra referred to in the paper could be reduced by proceeding in the manner outlined in reviewer's paper "Numerical analysis of forced vibration of beams" [AMR **6,** Rev. 2694] or reviewer's book "Fundamentals of vibration analysis," [McGraw-Hill Book Co., Inc., 1956]. But the tabular calculations themselves will not be materially affected by the method of their derivation. N. O. Myklestad, USA

1010. Philipson, L. L., On the role of extension in the flexural vibrations of rings, *J. appl. Mech.* **23,** 3, 364–366, Sept. 1956.

Love's equations for the flexural vibrations of thin rings are generalized to include the effects of the extension of the locus of the centroids of the cross sections. It is shown that, in general, the expressions for the "stress" components in terms of displacements are modified by the relaxation of the nonextensional assumptions and expressions are explicitly stated for the case of a plane circular ring arc. Rotatory inertia terms are also included.

The conditions for the use of the extensional and nonextensional theories are expressed in terms of the ring parameters. In general, it is shown that the nonextensional theory is valid for frequencies much lower than the pure radial vibration frequency.

M. V. Barton, USA

1011. Davenport, W. W., The accuracy of the substitute-stringer approach for determining the bending frequencies of multistringer box beams, *NACA TN* 3636, 28 pp., Apr. 1956.

Paper represents extension of previous investigation [AMR **7**, Rev. 2393] to structures more nearly representative of actual built-up box beams. An improved value for the substitute-stringer location is suggested. H. Parkus, Austria

1012. Kaczkowski, Z., Free vibration and buckling of a triangular plate (in Polish), *Arch. Mech. stos.* **8**, 1, 14–28, 1956.

Critical forces and frequencies of free vibration of plates in the form of right-angled triangles with equal sides adjacent to the right angle are obtained from the considerations concerning the modes of buckling and vibration of square plates. The problem has been solved by means of double Fourier series. For a plate simply supported on all edges, the quantities required are obtained in an explicit manner. For other types of plate support they should be determined by setting the determinant of an infinite system of equations equal to zero.

J. Mossakowski, Poland

1013. Karas, K., Rotation symmetric vibrations of a circular membrane under general conditions (in German), *Öst. Ing.-Arch.* 10, 2/3, 200–220, 1956.

The classical problem of vibrations of a thin circular membrane is generalized to include (1) the rotational inertia in the plane of the axis, (2) a slight radial variation in thickness and specific gravity of the membrane, (3) the mass of a ring attached to the outer circular boundary of the membrane, and (4) axial elastic suspension of that same ring. (1) and (2) affect the differential equation, whereas (3) and (4) affect the boundary conditions.

The differential equation for the amplitude function at free symmetric stationary vibrations is derived from equilibrium conditions and also from Hamilton's principle. The problem is also stated as an integro-differential equation, which is used to derive general conditions for definiteness.

The special case of uniform thickness and specific gravity is treated in more detail, and the eigenfrequencies are compared to those obtained by the Ritz method. J. Hult, USA

1014. Ellington, J. P., and McCallion, H., On running a machine through its resonant frequency, *J. roy. aero. Soc.* **60**, 549, 620–621, Sept. 1956.

A solution, in terms of known integrals, is obtained for the motion from rest of a machine, idealized as an undamped linear mass-spring system, when subjected to an exciting force whose frequency varies at a constant rate.

From authors' summary

1015. Summerfield, P. N., A study of the air and rock vibrations produced by impact testing of mine roof, *U. S. Bur. Mines Rep. of Investigations* 5251, 37 pp., Aug. 1956.

Report describes the first phase of a general investigation designed to ascertain whether an electronic roof-testing device can be developed that will improve the ability to detect "loose" or "drummy" roof rock over that possible by striking the roof with a sounding bar and noting the character of the air vibrations with the unaided ear or the rock vibrations with the fingers. The amplitude, frequency content, and duration of the vibrations produced by striking solid and drummy roof rock with a hammer or sounding bar have been measured. Results disclosed that there is a significant difference between the characteristics of the vibrations produced in solid and drummy roof. This difference is such that the design of an electronic device to indicate quantitatively the condition of the roof rock appears possible.

From author's summary

1016. Price, P., Suppression of the fluid-induced vibration of circular cylinders, *Proc. Amer. Soc. civ. Engrs.* **82**, EM 3 (*J. Engng. Mech. Div.*), Pap. 1030, 22 pp., July 1956.

An investigation of the vibration of circular cylinders in fluid streams has been made in an effort to evolve a means of suppressing the dangerous, wind-induced oscillation of tall steel smokestacks.

Exploratory vibration tests of plain and modified cylinders were made over a wide range of cylinder flexibility at subcritical Reynolds numbers in a water channel. These tests established that the enclosure of a cylinder within a concentric perforated shroud was the most effective vibration suppressor of the profile modifications investigated. Wind-tunnel tests proved the shroud to be an effective vibration suppressor at transitional and supercritical Reynolds numbers.

The drag coefficient of the shrouded cylinder was found to be substantially immune to Reynolds number effects in the range explored, and the value for a typical configuration was approximately 0.6. From author's summary

1017. Okabe, T., Hirata, K., and Kumai, T., Vibration measurements on a 32,000 ton D. W. super tanker, *Inter. Shipbldg. Progr.* **3**, 24, 409–414, Aug. 1956.

Present report deals with the results of the vibration measurements of a 32,000 ton d.w. super tanker on trial trips. All the natural frequencies of the flexural and torsional vibrations up to the blade frequency were observed, involving those of small amplitude measured by Geiger vibrographs and by the optical one which was made on trial. Since the measured critical frequencies of the flexural vibration of the hull are almost proportional to the number of nodes in both the ballast and loaded conditions, it is pointed out that the higher modes of hull vibration are considered to be of shearing vibration. The details of the theoretical investigations on the present observations are not presented except that one of the computed results of the vibration profile of the higher mode of shearing vibration of the hull is quoted as an example.

From authors' summary

1018. Wigle, B. M., Vibration-generator tests of the propeller shaft of the USS Forrestal (CVA59), *David W. Taylor Mod. Basin Rep.* 1007, 9 pp., July 1956.

A vibration-generator test was conducted on an Alloy 4 propeller shaft installed on the USS FORRESTAL (CVA59) to determine the natural frequencies and modes of lateral vibration. It is concluded that the first-order, first-mode critical whirling speed lies outside the operating speed range of the shaft. However, the second-mode, blade-frequency critical whirling speed is believed to occur within the operating speed range. The experimental data are compared with results predicted by theoretical methods.

From author's summary

Wave Motion in Solids, Impact

(See also Revs. 983, 1083)

1019. Hodge, P. G., Jr., Ultimate dynamic load of a circular cylindrical shell, Proc. second Midwestern Conf. solid Mech. Purdue Univ., Sept. 1955. 150–177.

A technique is presented for determining the deformation due to an arbitrary dynamic load. The theory used for the calculation of static collapse load and dynamic effects of loads in excess of this value is based on the assumption that the pressure consists of a static constant part and a dynamic part, that the axial effect of the pressure may be neglected, and that the shell is of a perfectly plastic-rigid material with simplified yield conditions. The dynamic load is due to a pressure wave and will depend both upon time and upon the distance of the pressure wave from its point of origin.

The results are applied to several examples and the essential conclusions are presented in figures which show the relation between the pressure wave distance and the maximum deflection.

Some objections to the theory and some suggestions for overcoming them are discussed. S. T. A. Ödman, Sweden

1020. Van Valkenburg, M. E., Clay, W. C., and Huth, J. H., Impact phenomena at high speeds, *J. appl. Phys.* **27,** 10, 1123-1129, Oct. 1956.

A study of high-speed, metal-to-metal impact in the velocity range 1 to 5 mm/μsec using $\frac{1}{8}$-in. diam spherical pellets is described. Pellet materials include aluminum, magnesium, steel, brass, lead, and zinc. Experiments relating to the mechanisms of cratering and the perforation of thin targets are presented. For the $\frac{1}{8}$-in. diam spherical pellets, it is found that the volume of the crater per unit energy of the impacting pellet is essentially constant for each material and that the penetration is proportional to the velocity of the pellet so long as the pellet velocity is less than the velocity of sound in the target material. An attempt to model very high speed impact by using soft wax targets in which the sonic velocity is less than the impacting velocity is outlined. From authors' summary

1021. Alter, B. E. K., and Curtis, C. W., Effect of strain rate on the propagation of a plastic strain pulse along a lead bar, *J. appl. Phys.* **27,** 9, 1079-1085, Sept. 1956.

Tests have been carried out to determine how pulses of plastic deformation disperse during propagation along a lead bar. The test bar was subjected to either a single or double compressive impulse wave. In the double impulse wave, the second half of the impulse followed the first half after an interval of 360μ sec. By making use of this double impulse, authors have shown that the dispersion cannot be due solely to the nonlinearity of a material that does not exhibit a strain-rate effect. All of the experimental evidence appears to indicate that the strain-rate effect plays an important role in the behavior of lead under longitudinal impact. E. A. Davis, USA

1022. Kolsky, H., The propagation of stress pulses in viscoelastic solids, *Phil. Mag.* (8) **1,** 8, 693-710, Aug. 1956.

This stimulating and interesting paper consists of an experimental and theoretical investigation of the propagation of stress wave pulses of short duration in three polymers: polythene (polyethylene), polystyrene and polymethyl methacrylate (perspex, lucite, or plexiglass). The bulk of the work is concerned with pulses produced in rods, $\frac{1}{2}$-in. diam, when a small charge of explosive is detonated at one end; the relation between stress and time in the pulses is measured by a condenser gage placed at the other end of the rod. Using rods of different lengths, varying between 8 in. and 7 ft, and recording repeated reflexions of the pulses, it is possible to derive families of (*stress, time*) curves for pulses which have traversed different distances in the rods.

The pulses are subject to two types of distortion as they recede from the origin: distortion due to dispersion and distortion due to the internal friction of the polymer material. The former is a geometrical effect, which is significant when the ratio of the length of the pulse to the diameter of the bar is not vanishingly small, and it sets a lower limit to the duration of the pulse which can be propagated in a given rod. The latter shows itself by the attenuation of the pulse and it gives rise to an increase in the length of the pulse and a decrease in the peak value of the stress as the pulse travels away from the origin.

In the case of polythene, the experimental curves were compared with results calculated from known experimental relationships giving the variation of the phase velocity and the attenuation coefficient of sinusoidal stress waves with the frequency. To carry out this comparison, it was assumed that the initial form of the pulse could be represented by a Dirac δ-function; a numerical Fourier synthesis was then performed to derive the form of the pulse at a finite distance from the origin. This procedure ignores two factors: the finiteness of the duration of the initial pulse and the distortion of the pulse due to dispersion. It is, however, possible to allow for these factors in an approximate manner by assuming, in the calculation, that the distance from the origin exceeds the actual distance traversed by the pulse. When this allowance is made, the agreement between the calculated and observed forms of the pulse is within the experimental error.

In the concluding section of the paper, it is pointed out that, for polythene and perspex, there exists a similarity relationship between the forms of the families of (*stress, time*) curves. An analysis of this similarity leads to the conclusion that a general solution of the problem of pulse propagation in thin rods of polymer can be given provided that the attenuation coefficient for sinusoidal waves is small and that it is proportional to the frequency. This condition seems to hold good for many polymers and, indeed, for many solids, provided relaxation phenomena and similar effects are absent. R. M. Davies, USA

1023. Broberg, K. B., Shock waves in elastic and elastic-plastic media, Kungl. Fortifikationsförvaltningen Befästningsbyrån Rap. 109-12, 141 pp., 1956.

Report gives interesting review of experiments on the propagation of elastic, plastic, and shock waves produced by impact and by the detonation of explosive charges. The theory of wave propagation in elastic and anelastic solids is discussed, and the propagation of spherically divergent stress waves is treated in detail. Tables of numerical values of dynamic stress-strain results for metals and other solids are presented and the fractures produced by the reflection of intense stress waves at the free boundaries of a specimen are described and discussed. The bibliography contains 71 references in the field, most of which are recent. H. Kolsky, USA

1024. Blake, R. E., and O'Hara, G. J., Dynamic response in three dimensions of linear elastic structures to independent motions of multiple supports, *Nav. Res. Lab. Rep.* 4739, 19 pp., May 1956.

The equations of response of three-dimensional linear elastic structures, having rotational and translational inertia, to dynamic loading by foundation motions are derived by using only the mathematical methods which are familiar to most engineering graduates. The structure has multiple foundations which are independent of each other in their motions in all directions. The differential equations describing the response of the structure are seen to be similar to that of a simple oscillator subjected to similar foundation motions. Duhamel's integral is applied to determine the response to arbitrary motions in all directions of the multiple foundations. The case of steady-state vibrations due to continuous harmonic foundation motions in arbitrary directions for all the foundations as well as one foundation is investigated, and the equations of response derived. The general equation for stress at any point is shown, and an example of its use is followed through.

This is an interim report on one phase of the problem; work is continuing. From authors' summary

Elasticity Theory

(See also Revs. 1050, 1055, 1058, 1060, 1062, 1063, 1064, 1075, 1087, 1090, 1091, 1093, 1094, 1165)

Book—1025. Savin, G. N., Stress concentrations at the edges of holes [Spannungserhöhung am Rande von Lochern], Berlin, VEB Verlag Technik, 1956, 448 pp. 45 DM.

This translation into German now makes Savin's work, originally published in Russian [AMR **5,** Rev. 1318], readily available. The quality of the translation (done by H. Neuber) is excellent. W. A. Nash, USA

Book—1026. Donato, L. F., Lectures on science of constructions. Part I. Elements of elasticity theory; resistance of materials [Lezioni di Scienza Delle Costruzioni. Parte Prima. Elementi di Teoria Dell' Elasticita; Resistenza dei Materiali],

d ed., Pisa, Colombo Cursi, 1955, ix + 282 pp. Paperbound. ire 3200.

This third edition of Vol. I of interesting textbook being used by rof. Donato at the University of Pisa and the Naval Academy in iverno, Italy has only minor revisions (2nd ed. reviewed by A. J. urelli, AMR **6**, Rev. 379). Chapters refer to: I. Mechanics of eformable bodies; II. Analysis of deformations; III. Equilibrium of olid elements; IV. Potential elastic energy; V. Theories of lastic equilibrium (Clapeyron, Betti, Maxwell, Menabrea, Castiglino, 2nd principle of deformation, Saint-Venant); VI. Isotropic olids; VII. Two-dimensional elastic systems; VIII. General spects of the Saint-Venant problem; IX. Action of simple normal rces; X. Simple bending; XI. Simple torsion; XII. Combined ending; XIII. Eccentric normal forces; XIV. Other combined rces; XV. Behavior of materials under loading; XVI. Criteria of sistance and safety (Coulomb, Guest, Mohr, Beltrami, Huber, enchy, v. Mises, Schleicher). J. J. Polivka, USA

1027. Stadelmaier, V. H. H., Stress-field in the semi-infinite nisotropic halfplane, subject to a concentrated load P (in German), *ZAMP* **7**, 5, 393–402, 1956.

The problem is solved with the aid of a stress function, the ifferential equation of which contains—in the nomenclature of . Voigt ["Lehrbuch der Kristallphysik," Leipzig und Berlin, 910]—the constants s'_{11}, s'_{22}, s'_{66}, s'_{12}, s'_{16} and s'_{26} (the x and y-axes ing in the half-plane). Author restricts the problem to the case here $s'_{16} = s'_{26} = 0$, but nevertheless the characteristic traits of nisotropy are maintained. On the other hand, it is extended to he case of a periodic repetition of P. The agreement with experiental data is remarkable. C. B. Biezeno, Holland

1028. Conway, H. D., The pressure distribution between two lastic bodies in contact, *ZAMP* **7**, 5, 460–465, 1956.

Paper deals first with the distribution of the contact pressure etween two two-dimensional, symmetrical, orthotropic bodies and hereafter with the same for two transversely isotropic solids of evolution. It is shown that, from a mathematical point of view, he two problems are identical with the corresponding problems of rigid two-dimensional punch on an orthotropic half plane. A few xamples, among other things wedges or cones in contact, are reated in some detail.

From author's summary by R. G. Boiten, Holland

1029. Schaefer, H., The three stress functions of the two-imensional plane continuum (in German), *Öst. Ing.-Arch.* **10**, 2/3, 67–277, 1956.

Using tensor notation, the stresses in a three-dimensional ontinuum are expressed in terms of vector fields; the vector fields re related to the loads applied. The particular case of the three-imensional continuum degenerating to a plane, loaded at its upper nd lower surfaces, is investigated in detail. The loads (and the tresses) can be expressed in this case in terms of a three-imensional vector and two additional functions. One component f the three-dimensional vector is proved to be identical with the iry stress function used in plane stress (or plane strain) roblems. The other two components (ϕ_1 and ϕ_2) are shown to be seful in the solution of plate problems, the derivatives of the omponents representing the bending and twisting moments of the late. It is shown that close analogies exist between ϕ_1 and ϕ_2 nd the strain components in case of plane strain. ϕ_1 and ϕ_2 are xpressed in terms of a biharmonic function. Boundary conditions o be satisfied by the various functions are discussed. Finally, n analogy existing between the problem stated and plane trusses oaded at right angles to their planes is pointed out.

G. Sved, South Australia

1030. Rongved, L., Force interior to one of two joined semi-nfinite solids, Proc. second Midwestern Conf. solid Mech., Purdue niv., Sept. 1955. 1–13.

Problem of two semi-infinite isotropic elastic solids connected along a plane with a concentrated force acting at a point in the interior of one solid is solved by Mindlin's method [AMR **7**, Rev. 2418] of obtaining the appropriate Papkovitch displacement functions. Solution of Kelvin's as well as other problems [AMR **7**, Rev. 2418; **9**, Rev. 3197] associated with force singularities in a half-space appear as special cases. Numerical results are not presented. K. Pister, USA

1031. Durelli, A. J., and Riley, W. F., Stress distribution in strips with hydrostatically loaded central circular holes, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955. 81–93.

Stress distribution was experimentally determined for the strips (width W) with a central circular hole (diameter D), D/W being 0.90, 0.80, 0.73, 0.62, and 0.51. Hydrostatic loading on the hole was applied by a special jig [AMR **7**, Rev. 3501]. Photoelastic tests were first applied and then a brittle coating method.

Curves are presented which show the distribution of maximum shear stress along the major and minor axes of the strip, and the distribution of maximum principal stress along the exterior and interior boundaries. In another figure, maximum shear stress on the exterior and interior boundaries is plotted against D/W. The maximum occurs on the exterior boundary for $D/W > 0.73$, and on the interior boundary, otherwise. A curve is also presented which compares the principal stress on the axes at the interior boundary with that computed using elementary formula for thick-walled cylinders. For $D/W < 0.70$, the experimental curve for the stress on the major axis agrees well with the computed curve.

S. Moriguti, Japan

1032. Mitra, D. N., Torsion of composite sections of different isotropic materials, *Bull. Calcutta math. Soc.* **47**, 3, 191–197, Sept. 1955.

Paper is devoted to the solution of the torsion problem of a cross section composed of two or more different isotropic materials, when the cross section can be mapped conformally on concentric circles, and the boundaries of the different regions are concentric circumferences. The mapping function is written in the form: $\sum_0^\infty \partial n \zeta^n$. Boundary conditions are established relating the torsion function $\varphi(xy)$, its conjugate $\psi(xy)$, and the stress function $\Psi(xy)$, of the different regions. From these expressions, relations are derived between the coefficients of the complex torsion functions of the isotropic regions and the coefficients of the mapping function. Then an expression is derived of the torsional rigidity, involving the constants of the mapping function. In the case of two concentric circles, the results agree with those of R. E. Payne, *Iowa State Coll. Jour. Sci.* 23–381–1949.

C. A. Sciammarella, Argentina

1033. Nowacki, W., On certain boundary problems of the theory of elasticity, *Bull. Acad. Polonaise Sci. Cl. IV* **3**, 4, 175–181, 1955.

Author considers a general elastic body with displacements prescribed over part of the surface, and external loads over the rest. It is shown that, in principle, one can obtain the stresses or displacements over the entire surface through the solution of a system of Fredholm integral equations. Similiar conclusions are reached for plates. No examples are given.

J. H. Huth, USA

1034. Nowacki, W., Thermal stresses in cylindrical shells (in Polish), *Arch. Mech. stos.* **8**, 1, 69–83, 1956.

A general equation for radial displacement in a cylindrical shell, caused by a nonuniform temperature rise $T(x, y, z) = r_0(x, y) z r(x, y)$, is obtained from the relation derived by W. M. Majsiel. The Green's function appearing in this formula has been calculated for

a simply supported shell from V. Z. Vlasov's equation by means of double trigonometrical series. If all the edges of the shell are clamped, it undergoes no radial displacement due to temperature rise. On the basis of the above, author solves a series of problems concerning shells with different (also discontinuous) boundary conditions, the final states of stress and strain being obtained by superposition of two parts, the first pertaining to a clamped shell subjected to the influence of temperature and the second to a simply supported shell loaded at the edges with moments of types corresponding to the type of support.

In the case of simple support or clamping along all edges of the shell, the solution is obtained in a closed form, involving, in general, simple infinite sums.

In the case of continous boundary conditions, the problem reduces to the solution of Fredholm integral equation of the first kind. Equations concerning the behavior of rectangular plates, subjected to the action of nonuniform temperature fields, constitute particular cases of the results obtained.

M. Sokolowski, Poland

1035. Weiner, J., An elastoplastic thermal-stress analysis of a free plate, *J. appl. Mech.* **23,** 3, 395–402, Sept. 1956.

Thermal stresses in a free plate of elastoplastic material subjected to a varying heat input over one face are determined. A heuristic solution is first found by suitable modifications of the known elastic solution. It is then verified that the solution satisfies all the conditions of the appropriate uniqueness theorem and represents therefore the unique solution to the problem. Residual stresses are determined and found to depend markedly on the peak magnitude of the heat input.

From author's summary by W. L. Esmeijer, Holland

1036. Vening Meinesz, F. A., Elasticity and plasticity, *Appl. sci. Res.* (*A*) **6,** 2/3, 205–225, 1956.

Proceeding in the usual way, author separates the stress and small-strain tensors into scalar and deviatoric parts. Assuming each can be analyzed separately, he shows this leads to the well-known requirement for two constants in a small-strain elastic theory. Using Mohr's circle construction, a graphical method is given for studying the Huber-Hencky-von Mises flow criterion. The procedure is then used to derive previously obtained results for plastic yielding in a thin plate. S. F. Borg, USA

Experimental Stress Analysis

(See also Revs. 988, 1073, 1086, 1108)

1037. Ondra, O., Moment distribution constants from models, *Proc. Amer. Soc. civ. Engrs.* **82,** ST 5 (*J. Struct. Div.*), Pap. 1058, 29 pp., Sept. 1956.

Author develops an experimental method of determining moment-distribution constants from models differing from well-established methods of Prof. Beggs and W. J. Eney. Here the ratio of moment to flexural stiffness is taken in a three-dimensional concept as a solid and a visual interpretation made. The ratio J/Q, that is the ratio of second to first moment, is a common parameter of the moment-distribution constants for members with constant and variable moment of inertia. This ratio is evaluated experimentally by weighing the solid defined above instead of mathematical integration. The equation of normal stiffness factor can be expressed in simple algebraic terms instead of the conventional formula involving five integrals. Arches can be analyzed very easily with this method, without sacrificing reliability.

S. K. Ghaswala, India

1038. Racke, H. H., Investigations on photoelastic models of prestressed pretensioned concrete beams (in German), *Schweiz. Arch.* **22,** 5, 150–163, May 1956.

1039. Racke, H. H., Stress distribution in the zones of the steel load transmission in prestressed pretensioned concrete beams of different eccentricities (in German), *Schweiz. Arch.* **22,** 6, 169–177, June 1956.

These are two new papers by the author who has recently contributed several papers in the field of photoelastic measurements. The application of new ideas by the author is certainly enriching the field. These papers study in detail the distribution of bond stresses in prestressed, pretensioned beams with different eccentricities of reinforcement. The problem is studied assuming a two-dimensional stress distribution. The results obtained are important in the field of reinforced-concrete technology but it seems to the reviewer that the most important phase of the papers is the development of new stress analysis materials and techniques.

Particularly worth mentioning is the soft plastic used by the author, exhibiting very high optical sensitivity and very low modulus of elasticity. The need of materials of this kind is felt at the present time in many countries and in view of many applications. The reviewer has developed a similar material for photoelastic dynamic applications and for static and dynamic grid measurements (papers recently presented to the International Congress in Applied Mechanics and S.E.S.A.). The reviewer thinks it would be advisable to include a stress-strain curve of the material Vulkollan used by the author.

The relative elastic properties of steel and concrete have been simulated well in the heterogeneous model. The author may like to know that a contribution to the determination of bond stresses in a quite similar problem was made by the reviewer and published in the *J. appl. Mech.*, June, 1955. The reviewer wonders whether in Figure 5 of the second paper the isostatic line which is indicated as belonging to the two families is actually a singular line. In similar problems it has been found that there are 4 singular points in the neighborhood of the corner rather than a singular line, and this seems substantiated by some of the photographs shown in the first paper by the author.

A. J. Durelli, USA

1040. Leist, K., Schleiermacher, K., and Weber, J., Photoelastic investigations on turbine blades, *Dtsch. Versuch. Luftfahrt E.V. Rep.* no. 6, 56 pp., Mar. 1956.

1041. Wheeler, J. E., Measured strains in a swept tapered tube Part I, *Aero. Res. Lab. Melbourne, Austral.* SH. 237, 16 pp. + 18 figs., Jan. 1956.

Stresses have been calculated from strains measured in a swept tapered tube, representative of a two-spar swept wing torsion box, with ribs in line-of-flight. These are compared, at a section far removed from the root, with those given by a theory due to Wittrick and also with the stresses predicted by the simple theories of bending and torsion.

Agreement between either theory and test results is quite good but there is indication that a theory taking account of rib flexibility would give closer agreement. From author's summary

1042. Buchanan, J. G., and Thurston, R. C. A., The measurement of crack depths by the direct-current conduction method, *Nondestructive Testing* **14,** 5, 36–39, 43–44, Sept./Oct. 1956.

Rods, Beams, Cables, Machine Elements

(See also Revs. 991, 1003, 1004, 1006, 1008, 1021, 1065, 1078)

1043. Jones, E. E., On the flexure of a stepped cantilever beam, *J. aero. Sci.* **23,** 11, 1057–1058 (Readers' Forum), Nov. 1956.

Simple integral formula for deflection of a cantilever beam with

nonuniform, stepped cross section is given. Special case of the beam under its own weight is discussed and results suited for computational work are introduced. Method can be extended for point loads and moments and distributed moments. Its simplicity is due to the fact that both boundary conditions of the problem (deflection and slope of the deflection curve) are given for the fixed end of the cantilever beam.

V. Kopriva, Czechoslovakia

1044. Boley, B. A., and Tolins, I. S., On the stresses and deflections of rectangular beams, *J. appl. Mech.* **23,** 3, 339–342, Sept. 1956.

Authors use a method of successive approximations previously described [AMR **9,** Rev. 1393] to solve the biharmonic equation and so obtain approximate expressions for the stresses and displacements for certain types of loading. The form of the approximations requires that the loads be smoothly distributed in a spanwise direction. The first approximation verifies the Bernoulli-Euler hypothesis for beams. A comparison is made with the elementary beam theory as modified by Timoshenko to include shearing deformation. J. Fulton, Scotland

1045. Levy, J. C., Deflection of a beam referred to any set of rectangular centroidal axes, *J. appl. Mech.* **23,** 3, 464–467, Sept. 1956.

The deflection of a uniform beam subjected to unsymmetrical bending is expressed in terms of moments and products of inertia of the beam referred to arbitrary rectangular axes through the centroid of a right section, and component deflection coefficients which depend on the loading and the dimensions. Application of the method avoids determining the location of the principal axes of inertia, and the magnitudes of the corresponding moments and products of inertia. E. E. Jones, England

1046. Poschl, K., On a special integral equation (in German), *ZAMM* **36,** 5/6, 161–167, May/June 1956.

Problem arises from two parallel, fixed-ended beams bent toward each other by a wrapping of wire that begins at one end and proceeds toward the other. Wire is wrapped under constant tension so that as wrapping proceeds the tension in initial portion of wire decreases because of beam deflection produced by subsequent wrapping. Question posed is: what is deflection curve of beam at any stage of wrapping? Deflection curve of beam is integrated effect of all wrappings and this gives an integral equation (Fredholm) of well-known form. Author shows how problem can be solved but does not give any numerical examples.

G. W. Housner, USA

1047. Eggwertz, S., Strength of 75S-T integral compression skins in box-beams under pure bending, *Flygtekn. Försöksanst. Medd. Rep.* 64, 42 pp., Feb. 1956.

Eight one-cell and three two-cell box-beams with unstiffened 75S-T aluminum-alloy compression skins integrally connected to the webs have been tested under pure bending, the strain being measured at a large number of points, particularly on the compression side. The main interest has concerned the stress distribution at failure, and the maximum average stress in the compression skin has been related to the buckling stress and the maximum corner stress, which is approximately equal to the yield strength of the material. After comparing the test results with published theoretical and experimental investigations on plate sections under pure compression, an empirical procedure is advanced for calculating the maximum bending moment that can be applied to box-beams with two or more webs. This procedure is thought to be applicable to extruded aluminum and magnesium alloys and also, roughly, to rolled plates of the same materials in riveted structures. From author's summary

1048. Bullen, N. I., The influence of rope stretch on tension variations in arresting gears, *Aero. Res. Counc. Lond. Rep. Mem.* 2964, 38 pp., 1956.

Equations of motion are set up for a system consisting of an aircraft and an arresting gear. The analysis differs from work previously done by the assumption of elasticity, mass, and friction in the wire cable used. The resulting equations are integrated step by step. Comparison of the results with observed rope tensions and accelerations indicates good agreement, and it is concluded that the rope elasticity accounts for hitherto unexplained observed oscillations in rope tensions.

F. W. Niedenfuhr, USA

1049. Koennecke, W., Improvements in securing screws. Part 1: Spring washers and their increase of efficiency (in German), *Forsch. Geb. Ing.-Wes.* **22,** 3, 85–94, 1956.

The turning moments for tightening and loosening the axial loads, the springiness, and the security effect of screws were measured by means of new high-precision measuring devices. A comparison between the security effects of various types of conventional spring washers and the conclusions drawn from the results led to entirely new surfaces and constructions of washers which guarantee securing properties hitherto unreached.

From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 1005, 1007, 1012, 1013, 1019, 1029, 1033, 1034, 1035, 1069, 1132)

1050. Evan-Iwanowski, R. M., Stress solutions for an infinite plate with triangular inlay, *J. appl. Mech.* **23,** 3, 336–338, Sept. 1956.

Muskhelishvili's method of solving problems of elastic plates with openings by means of functions of complex variable is applied to the case of infinite plate with triangular inlay. Similar problem, but with prescribed tensions on the boundary, was solved by Hu Nan Chu. Author prescribes displacements on the boundary: inlay remains rigid and is rigidly attached to the plate. Final solutions and numerical examples are given for: (1) uniform tension at infinity; (2) concentrated force; (3) moment acting on triangular inlay. H. Fernandez Long, Argentina

1051. Chien, W.-Z., Problem of large deflection of circular plate, *Arch. Mech. stos.* **8,**1, 3–12, 1956.

A thin isotropic circular plate of constant thickness, subjected to a uniform load q, acting perpendicularly to the plane of the plate, is considered. The plate is elastically clamped along its edges. The clamping moments are proportional to the slope of the elastic surface and the radial stress is proportional to the radial displacements of the edge. The coefficients of proportionality can take any values between zero and infinity.

The iteration method is used, enabling one to obtain in a quick manner sufficiently accurate results, provided that the parameter W_m expressing the ratio of the maximum deflection to the thickness of the plate is sufficiently small. Then the fifth and the higher powers of that parameter can be disregarded.

The same method is used for the determination of the deflection of a circular plate subjected to the simultaneous action of a uniform load and a concentrated force at the center.

Z. Kaczkowski, Poland

1052. Nowacki, W., Assemblage stresses in plates (in Polish), *Arch. Mech. stos.* **8,** 2, 215–232, 1956.

A plate deformed before placing it on supports lying in the same plane is the subject of this paper. The initial deformation, originating during the production of the plate, is free from any internal stresses. Such a plate can be put on the supports only when external force is used. This causes so-called assemblage stresses. The general method of computation of these stresses is given.

The solution of the problem is based on the integral expression obtained from the equation of virtual work. The expression having

a form of a surface integral is represented by using Green's transformation in the form of a sum of two integrals: a curvilinear and a surface integral. This form is more convenient and, in the case of a simply supported plate or a plate rigidly fixed along its periphery, leads to very simple expressions. In the case of a plate with discontinuous boundary conditions the solution is obtainable in the form of a system of Fredholm integral equations of the first kind. Examples of application of the method for calculating assemblage stresses concern rectangular plates with various initial deformations. Z. Kaczkowski, Poland

1053. Nowacki, W., and Olesiak, Z., The problem of a circular plate partially clamped and partially simply supported along the periphery (in Polish), *Arch. Mech. stos.* **8**, 2, 233–255, 1956.

A circular plate partially simply supported on segments of its periphery and clamped at the remaining segments, compressed by forces q uniformly distributed in the plane of the plate, is considered. A periodic load acting perpendicularly to the plate provokes forced vibration with angular frequency ω. The problem consists in: (1) Determination of the amplitude of forced vibration; (2) calculation of the frequency of free vibration; (3) determination of the critical values of the normal load; and (4) determination of the deflection surface of the plate in the case of a static load.

A plate simply supported on its periphery is assumed as a basic system. An unknown bending moment, periodically variable, is assumed to act on part of the periphery. The condition of clamping of that part of the boundary leads to a Fredholm integral equation of the first kind. The kernel of this equation constitutes an infinite series in Bessel functions.

The paper is illustrated by some numerical examples Approximate solutions are obtained by replacing the integrals by summation formulas. Z. Kaczkowski, Poland

1054. Szelagowski, F., One-directional tension of an annular plate, *Bull. Acad. Polonaise Sci. Cl. IV* **3**, 4, 189–193, 1955.

Title problem is solved by expressing the stress functions for the problem as truncated Laurent's series for the cases (a) the inner boundary is rigid and (b) a uniform tension acts along diameter of inner boundary directed in same sense as stress on periphery of plate.

Author uses but three terms of series to find expressions for the stresses in the plate. He suggests his solutions will approximate a strip under one-directional tension having (1) a rigid circular inclusion (a), or (2) a circular hole with normal stresses, as in case (b).

Author gives no numerical results nor does he suggest the degree of approximation of his answers. R. E. Beckett, USA

1055. Paria, G., Stress distribution in thin aeolotropic plates, *Bull. Calcutta math. Soc.* **46**, 3, 153–161, Sept. 1954.

In a previous paper, a method of Fourier transform of the stress function has been given for the solution of the generalized plane stress problems, when the material of the plate has two planes of elastic symmetry at right angles to each other and also at right angles to the plane of the plate. In the present paper, this method has been applied to find the stress distribution in (1) a semi-infinite plate with a concentrated force acting at an internal point and (2) a strip of infinite length but of finite breadth acted on by (a) a concentrated force and (b) an isolated couple within it.

From author's summary

1056. Higginson, G. R., Strength of a tube under local external pressure, *Engineer, Lond.* **202**, 5253, 428–430, Sept. 1956.

Paper considers the case of a long tube of ideal plastic material subjected to external pressure over a short finite length. For determining the strength, i.e., the load at which major permanent deformation commences, pressures required to cause shear and bending failures are calculated separately. The smaller of the two pressures is taken as the estimated strength. To obtain an approximate solution, work method is used.

A. M. Sen Gupta, India

1057. Nowinski, J., Application of the Laplace transformation to problems of torsion of thin-walled tubes (in Polish), *Arch. Mech. stos.* **8**, 1, 111–119, 1956.

Author applies the Laplace transformation to problems of torsion of thin-walled cylindrical tubes with open cross sections. He uses the theory of V. Z. Vlasov as well as his own results as convenient for solving boundary-value problems.

To obtain a general solution, the assumption of a Winkler-type elastic medium surrounding the tube is made. The corresponding differential equation in the case of uniformly distributed twisting moments is solved by means of the Laplace transformation. Then the case of load consisting of concentrated moments is discussed, using transition to the limits in the transformed relations. This simple procedure gives the so-called universal formula for the angle of twist. Finally, an example of solving a boundary-value problem, the approximate solution of which is known, is presented in detail. T. Iwinski, Poland

1058. Rudiger, V. D., Stresses and strains of curved surfaces with elliptical base (in German), *Öst. Ing.-Arch.* **10**, 1, 66–74, 1956.

Using the formalism of differential geometry, differential equations are developed for the computation of stresses and displacements in very general shells under arbitrary loading conditions. The main limitation placed upon the geometry of the shell is that the projection of its boundary in some plane must be an ellipse. These differential equations are solved for a number of special cases.

This work constitutes a generalization of a 1934 paper by A. Pucher in which the projection of a doubly curved surface on an arbitrary plane was assumed to be a circle.

S. B. Batdorf, USA

1059. Parme, A. L., Hyperbolic paraboloids and other shells of double curvature, *Proc. Amer. Soc. civ. Engrs.* **82**, ST 5 (*J. Struct. Div.*), Pap. 1057, 32 pp., Sept. 1956.

Utilizing the membrane theory of shells and employing a simplification of transforming actual forces that act on a curved shell into fictitious forces that act on orthogonal (x,y,z) projections of the shell surface [See "Uber den Spannungszustand in gekrummten Flachen" by A. Pucher, *Beton u. Eisen*, **33**, 298–304, 1934], author derives a partial differential equation that describes the behavior of a gravity-loaded shell in terms of a stress function F. The cases of a hyperbolic paraboloid surface ($z = k\,x\,y$, where k is a constant) and of an elliptic paraboloid surface ($z = k_x\,x^2 + k_y\,y^2$, where k_x and k_y are constants) are treated analytically. Numerical values of stresses in the shell are given in the form of tables and graphs. Since the differential equation of the shell is difficult to solve in general, author suggests that numerical methods (finite differences, relaxation, etc.) are more practical for most shells of double curvature. A. P. Boresi, USA

1060. McComb, H. G., Jr., Torsional stiffness of thin-walled shells having reinforcing cores and rectangular, triangular, or diamond cross section, *NACA TN* 3749, 35 pp., Oct. 1956.

A theoretical study is made of the torsion of composite prismatic bars consisting of an outer thin-walled shell to which is bonded a core of a different material. Combination of Saint-Venant and Bredt theories leads to requirements that the stress function for the core satisfy Poisson's equation and a single boundary condition at interface. A series solution is found for the rectangular cross section, and approximate solutions obtained by variational methods for triangular and diamond cross sections. Results for torsional stiffnesses are presented graphically over a wide range of section-thickness ratios and ratios of shear moluli of core and shell materials, thus forming a concise design reference for aerodynamic shapes. Simple procedure of adding individual torsional stiffnesses of core and shell, which neglects stiffening effect of bond, is shown to give values which are smaller than present results by less than 5% for rectangular sections, but which are considerably lower

for certain triangular and diamond cross sections.

L. Maunder, USA

1061. Salvadori, M. G., and Sherman, R., Bending stresses in edge stiffened domes, *Proc. Amer. Soc. civ. Engrs.* **82,** *ST 4 (J. Struct. Div.)*, Pap. 1021, 28 pp., July 1956.

Bending moments and shears in certain types of thin shells of revolution, stiffened by an edge beam, are obtained and graphs for their evaluation are given. Variable, symmetrical live and dead loads are considered, together with temperature and shrinkage stresses.

Approximate but accurate values of the maximum moments in the shell and supporting cylinder are derived by means of the same graphs, when the dome is built-in into a cylinder and stiffened by an edge beam. From authors' summary

1062. Ambartsumyan, S. A., On the theory of anisotropic shallow shells, *NACA TM* 1424, 11 pp., Dec. 1956.

1063. Ambartsumyan, S. A., On the calculation of shallow shells, *NACA TM* 1425, 11 pp., Dec. 1956.

1064. Nazarov, A. A., On the theory of thin shallow shells, *NACA TM* 1426, 7 pp., Dec. 1956.

Buckling Problems

(See also Revs. 1004, 1007, 1012)

1065. Vasarhelyi, D. D., and Knudson, R. O., Thin-walled box beams under pure bending, *Publ. int. Assn. Bridge struct. Engng.* 15, 231-245, 1955.

In analyzing the stress distribution of thin-wall sections under pure bending moment, author assumes that when the compression elements buckle they keep on supporting the buckling stress. This behavior is identical to local yielding of ideal plastic materials for which the deformation of a part of the structure may progress without any increase in stress. Author then presents a general formula for the stress-bending moment relation in pure bending of sections, parts of which yield or buckle. This formula is applied in the case of thin-wall box beam. The values so obtained are compared with experimental results.

Author did not include discussions on the concept of effective widths of buckled plates, which has been widely used by the aeronautical engineers for stress analysis of thin-shell structures.

T. H. H. Pian, USA

1066. Robinson, J. R., The buckling and bending of orthotropic sandwich panels with all edges simply-supported, *Aero. Quart.* **6,** 2, 125-148, May 1955.

Paper summarizes the existing theory. Two special types of symmetrical sandwiches, that of a sandwich having zero core flexural stiffnesses and a corrugated core sandwich, are considered, and curves giving the critical buckling end load per inch are presented. An approximate solution is also given for the bending of sandwich panels under the action of an axial compressive load and a uniform lateral pressure. Curves are presented giving the maximum bending moments in a corrugated core sandwich panel. J. F. Besseling, Holland

1067. Masur, E. F., An extended upper bound theorem on the ultimate loads of buckled redundant trusses, *Quart. appl. Math.* 14, 3, 315-317 (Notes), Oct. 1956.

Note is intended to supplement an earlier paper from the same author. See AMR **7,** Rev. 2134. S. E. Kindem, Norway

1068. Lin, T. H., Creep deflection of viscoelastic plate under uniform edge compression, *J. aero. Sci.* **23,** 9, 883-886, Sept. 1956.

Analytical method of calculating creep deflection of viscoelastic columns [AMR **7,** Rev. 3567] is extended to obtain deflection of simply supported plates with in-plane compressive edge forces. The plate material is assumed to have linear viscoelastic properties. The analysis is based on small-deflection theory, assuming that plate has a small initial deflection. General discussion is followed by a numerical example for a square plate. No experimental verification of the results is given.

E. P. Popov, USA

1069. Radhakrishnan, S., Plastic buckling of circular cylinders, *J. aero. Sci.* **23,** 9, 892-894 (Readers' Forum), Sept. 1956.

Two cases of loading are considered: torsion, and lateral pressure combined with axial load. Solutions are given which were obtained from Donnell's equations with assumptions of (1) small strain theory, (2) the Hencky-Nadai stress-strain law with Poisson's ratio 0.5, and (3) full plasticity during buckling. An interesting result in the combined loads problem is that, in certain ranges, the critical lateral pressure increases with axial compressive load. Suitable experimental data were not available to check this conclusion, but reviewer believes that spot checks on the theory might have been made by referring to R. G. Sturm's useful work ["A study of the collapsing pressure of thin-walled cylinders," University of Illinois Experiment Station Bulletin Series no. 329, Nov. 1941]. Author intends to publish more complete results later. A. D. Topping, USA

Joints and Joining Methods

1070. Radcliffe, B. M., Design of timber roof truss with nail-glued connections, ASME Ann. Meet., New York, N. Y., Nov. 1956, Pap. 56-A-180, 7 pp. + 9 figs.

Because of the stiffness of the relatively long joints in trussed rafters with nail-glued plywood gusset plates, such structures are statically indeterminate and cannot be designed as pin-connected frames.

Using scale models, stresses and moments were determined on the basis of data obtained with electrical resistance strain gages. The model constants were then applied to the design of a 32-ft-span king-post trussed rafter. Static tests on such a structure were performed by loading the rafters with weights which were distributed uniformly.

While the design called for a loading of 80 plf, a test load of 140 plf was applied at a deflection amounting to 70% of 1/360 of the span. Failure occurred at a test load of 218 plf.

The stress analysis for the model was substained by this test, with the points of contraflexure at the positions of zero moment and with the center post-stressed in tension.

The ½-in. plywood gusset plates were nail-glued with casein glue and with 2 and 3 rows of 4d common wire nails spaced 4 in. along the grain of the 2 × 4 and 2 × 6 members, respectively.

In reviewer's opinion, such nail-glued trussed rafters should provide satisfactory service provided the gluing operation is performed under controlled conditions. Field gluing cannot be recommended. E. G. Stern, USA

1071. Hiba, Z., Failure of nailed roof trusses (in Serbian), *Naše Gradevinarstvo* **10,** 3, 364-368, Mar. 1956.

Failure of several nailed timber trusses investigated by author are described and test results compared with calculation of stresses. It was found that secondary stresses in certain cases are of the same intensity as normally calculated primary stresses. It is concluded that trusses consisting of nailed boards are justified; however, special attention should be given to the design and quality of timber used. References: Engesser, Habel-Zacher, Karlsen, Laskus-Schroder, Mohler, Bub.

J. J. Polivka, USA

1072. Jones, J., Effect of bearing ratio on static strength of riveted joints, *Proc. Amer. Soc. civ. Engrs.* **82,** ST6 (*J. Struct. Div.*), Pap. 1108, 10 pp., Nov. 1956.

Paper offers evidence that in riveted joints of usual structural proportions, subjected to substantially static loads, the joint strength will not be reduced if the ratio of rivet bearing stress to axial or shearing stress is increased above that sanctioned by most specifications for steel buildings and bridges.

From author's summary

1073. Mylonas, C., Experiments on composite models with applications to cemented joints, *Aero. Res. tech. Notes Bull.* 161, 10 pp., May 1956.

Structures

(See also Revs. 1011, 1015, 1023, 1038, 1039, 1047, 1066, 1070, 1104, 1108, 1111, 1123, 1130, 1134, 1180, 1188, 1254, 1292, 1294)

Book—1074. Abbett, R. W., edited by, American civil engineering practice, Vol. 1, xii + 1020 pp. + index. $15; **Vol. 11,** xiii + 917 pp. + index. $15, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956.

Books present the fundamental principles, procedures, and data of civil engineering practice in concise form with illustrations from current practice.

Volume I has eleven sections devoted to metropolitan and community planning, surveying, traffic highways, airports, railroads, soil mechanics and site planning, foundations, earthwork, tunnels, and mathematical tables. Volume II has ten sections: hydraulics and pumping, hydrology, dams, river engineering, hydroelectric power, irrigation and land drainage, public water supply, sewerage and sewage disposal, refuse collection and disposal, and harbor engineering.

Reviewer believes these books are a good and concise reference on the listed subjects and concurs with the editor that the contributors are distinguished engineers.

J. N. Thompson, USA

1075. Falconer, B. H., Theory of the stresses induced in reinforced concrete by applied two-dimensional stress, *J. Amer. Concr. Inst.* **28,** 3, 277–293, Sept. 1956.

Problem of concrete reinforced in two directions and subjected to two-dimensional stresses. Results are compared to American Concrete Institute Code and British Standard Code of Practice.

A.-t. Yu, USA

1076. Skalmowski, W., Prefabrication of building elements from dross (in Polish), *Przegl. tech.* **75,** 12, 438–439, Dec. 1954.

This is a description of research on a new joining material, similar to cement and produced from dross. It has strength around 120 kg/cm². It is used in production of bricks, blocks, and other building elements. These are used in USSR as well.

M. Z. Krzywoblocki, USA

1077. Zezelj, B., Are there any reasons to prefer steel structures rather than reinforced and prestressed concrete structures?, *Naše Gradevinarstvo* **10,** 1, 29–30, Jan. 1956.

This article refers to the same subject published in "Stroiteljnaja gazeta," Moscow, and expresses the opinion of Yugoslav engineers. It is emphasized that the enormous progress in concrete structures during the past 20–30 years not only as to material but also in design and construction methods substantiates its preference in many cases. Following advantages of concrete are discussed: (1) Greater safety factor; (2) practically vanishing maintenance, in comparison with steady and costly protection of steel against corrosion; (3) Economy of construction (with exception of some long-span structures) with high-strength, light-weight and prestressed concrete with prefabricated elements: (4) short time for erection with standardized precast structural members; (5) better esthetic and artistic characteristics.

J. J. Polivka, USA

1078. Hendry, A. W., Struct, E., and Jaeger, L. G., The load distribution in interconnected bridge girders with special reference to continuous beams, *Publ. int. Assn. Bridge struct. Engng.* **15,** 95–116, 1955.

This paper contains two parts: (1) A summarized version of a new method for calculating interconnected bridge girders which has been published in *Struct. Engr.* and analyzed previously by this reviewer [AMR 9, Rev. 3925]; (2) the application of foregoing method to the analysis of interconnected continuous beams. This problem is solved in two steps: (a) first, the bridge is treated as a simple span between the first and last support and the applied loads are distributed in the usual manner; (b) support forces are then introduced and their magnitudes are calculated from the requirement that the deflections at the support points must be zero.

As a numerical example, the influence line is calculated for bending moment at the mid-point of the first span of a two-span continuous bridge.

C. Massonnet, Belgium

1079. VanDyke, J. C., Recent developments in engineered timber construction, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–136, 8 pp.

Author presents the background which resulted in the development of today's engineered timber structures, such as the glued laminated arches of 250-ft span and 300-ft length at West Palm Beach, Fla.

Since the paper was written, this record span has been exceeded by a laminated arch of 300-ft span which was under construction at the time the paper was presented. Engineered timber construction has a promising future.

E. G. Stern, USA

1080. Milosavjevic, M., How snow affects roof structures, *Naše Gradevinarstvo* **10,** 1, 31–33, Jan. 1956.

Article refers to failures and serious damage to buildings in Železare, 1954, caused by an unusual depth of snow and presents suggestions on how to consider this type of live load for reliable safety. In many European countries the snow load is specified 15–20 lb/sq ft (75–100 kg/m²) up to an elevation of 1000 ft. In accordance with the Yugoslav building code the snow load is to be increased with increasing altitude, i. e., $S(\text{in kg/m}^2) = 75 \times \frac{A-500}{4}$. From this formula, roofs in Železare with the elevation of 657 m (2150 ft) should be designed for 115 kg/m² (23.5 lb/sq ft) snow load. In that particular disaster area the maximum snow load was found to be 66 lb/sq ft (325 kg/m²) or, with the depth of 3.53 ft (109 cm), 18.8 lb/cu ft (300 kg/m³). The failures occurred with steel and timber roof structures of relatively light dead load, and it is evident that the increase of the live load of 46 lb/sq ft could not cause failure of a concrete roof. Respective revision of the building code is recommended.

J. J. Polivka, USA

1081. Morgan, V. A., Analysis of a frame with three bays, Concr. constr. Engng. **51,** 8, 451–459, Aug. 1956.

1082. Wilde, P., Curvilinear girders of thin-walled open cross-section elements (in Polish), *Arch. Mech. stos.* **8,** 1, 41–50, 1956.

A system of differential equations determining the deformed shape of a girder curved in the horizontal plane is obtained by means of the principle of virtual work. Using the equilibrium conditions for twisting forces, differential equations for thin-walled open cross section are established. Next, the problem of a continuously loaded cantilever is solved taking the boundary conditions into consideration, the angle of twist and the bimoment being determined. A numerical example is presented.

Moreover, an approximate solution by means of Fourier series is obtained. A comparative numerical computation of the bimoment using relations for straight and curved bars shows a difference of

results approaching 22% for the angle between the end cross sections equal to 90°. It is obvious that this error decreases with decreasing angle. J. Rutecki, Poland

1083. Glazbrook, C. S., Earthquake stresses in building floors, *Proc. Amer. Soc. civ. Engrs.* **82**, ST6, (*J. Struct. Div.*), Pap. 1098, 6 pp., Nov. 1956.

1084. Styrikovich, M. A., Working process of super-high-pressure once-through boilers, *Combustion* **28**, 3, 49–53, Sept. 1956.

Paper shows that at pressures above 2275 psia once-through-boiler working processes change greatly, especially with respect to heat exchange from heating surfaces to the working substance and the behavior of the solids contained in feedwater. The range of flow velocity, dryness factor, and heat flux, within which stable nucleate boiling occurs, greatly decreases on nearing the critical pressure. With increased pressure, the solubility of a number of substances in steam grows, determining steam contamination of once-through boilers. At a pressure up to 2844 psia, effective extraction of salts from the cycle and reduction of the requirements as to feedwater may be achieved by means of separators. At higher pressures it is necessary to limit the salts entering the cycle in every way and to use various methods for the extraction of salts from the cycle.

From author's summary by W. Gumz, Germany

1085. Pray, R. F., and Jensen, C., Welded top plate beam-column connections, *Welding J.* **35**, 7, 338s–347s, July 1956.

A method of analyzing a top-plate type of beam-column connection has been presented, accompanied by a test of a built-up two-way beam-column connection. Also presented is a tension test arrangement whereby new type top-plates can be tested for adequacy without resorting to the complication of the built-up assembly. The potentialities of the proposed four top-plate-type connections are: (1) All of the proposed top-plate design methods permit the beams to be cut to standard structural tolerances. (2) They are planned on the basis of downhand welding of the field welds. (3) Proposed Design Method I is a conservative one that is about as simple to apply as a fully fixed direct welded connection and has the same economy of beam design. (4) Method II is a conservative one similar to I except that no flaring of the top-plate is required. (5) Method III utilizes the same procedure for the beam as I, provides a little economy of top-plate over I, reduces the maximum moment which the beam may throw into the column. (6) Method IV shows how wind or other lateral loads may be combined with gravity loads.

The predicted moment-rotation characteristics of the four designs are given.

Once the provision for self-limiting plastic deformation is accepted, it is readily seen that the top-plate beam-column connection has economic potentialities.

From authors' summary by D. Vasarhelyi, USA

1086. Zender, G. W., Comparison of theoretical stresses and deflections of multicell wings with experimental results obtained from plastic models, NACA TN 3813, 32 pp., Nov. 1956.

The experimental deflections and stresses of six plastic multicell-wing models of unswept, delta, and swept planform are presented and compared with previously published theoretical results obtained by the electrical-analog method. The comparisons indicate that the theory is reliable for evaluating deflections. In addition, the model tests indicate that the theory is reliable for stresses except near the leading edge of the delta wings and the leading and trailing edges of the swept wings where the simplifications employed in idealizing the actual structure and local effects of the concentrated loading introduce appreciable errors.

From author's summary

1087. Mansfield, E. H., Stress concentrations at a cut-out in a swept wing, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2823, 21 pp., 1954.

The stress concentrations are determined for a panel, bounded by main load-carrying members and an oblique edge, such as might occur at a cut-out in a swept wing. The solutions given are exact and cover the effects of a member along the oblique edge and of closely-spaced stringers attached to the panel.

From author's summary

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 1021, 1022, 1035, 1036, 1068, 1069, 1118, 1123, 1136, 1278, 1290)

Book—1088. Sokolovskii, V. V., Theory of plasticity [**Theorie der Plastizitat**], Berlin, VEB Verlag Technik, 1955, 484 pp. 28.40 DM

Originally published in Russian [AMR **5**, *Rev. 1071], this* translation into German now makes Sokolovskii's work readily available. The translation is excellent and follows the original work very well. W. A. Nash, USA

1089. Olszak, W., and Urbanowski, W., The orthotropy and the nonhomogeneity in the theory of plasticity (in Polish), *Arch. Mech. stos.* **8**, 1, 85–110, 1956.

The physical sense of the idea of a nonhomogeneous anisotropic body is considered, introducing the flow function expressed by means of a homogeneous quadratic form of stresses, the coefficients being not constants but functions of the point considered. The yield condition is based on the assumption of constant flow function ψ. An anisotropic body of "uniform" or "single function" nonhomogeneity constitutes a particular case of a nonhomogeneous body of curvilinear anisotropy. The subsequent considerations concern nonhomogeneous orthotropic bodies, for which the flow function depends only on the squares of the differences between the normal stresses and the squares of the shear stresses in a system connected with the principal directions of orthotropy. The transition from the coefficients of the function ψ to the three yield points in the principal directions of orthotropy for such bodies can be done in an easy manner.

The relations for the deformation rates are obtained by partial differentiation of ψ. Here also the point functions appearing in ψ play the most important role. A homogeneous rectilinearly orthotropic body for which ψ has six constant coefficients is a particular case of such a body.

Two cases of plastic flow, (a) for a plane state of stress and (b) for a plane state of strain, are considered as examples of application of the theory. The yield condition for both states is established. Introducing the flow function and the stress function we obtain the solution of the problem in the form of a nonlinear partial differential equation. The forms of this equation are represented in a table for a few systems of coordinates: Cartesian, isothermal polar, ordinary polar, elliptical and parabolic. Finally, an example of a body of the polar type of orthotropy and of the axially symmetrical type of nonhomogeneity under an axially symmetrical load is considered.

J. Naleszkiewicz, Poland

1090. Whalley, E., The design of pressure vessels subjected to thermal stress. I. General theory for monoblock vessels, *Canad. J. Technol.* **34**, 5, 268–290, Sept. 1956.

Author finds radial and circumferential stress components in spherical and cylindrical pressure vessels subject to arbitrary radial temperature distributions and to internal and external pressures. The material is non-workhardening and so the stress fields are statically determinate. Design criteria based on brittle fracture, ductility and shakedown are found. (Reviewer has shown

how workhardening can be included, *J. Mech. Phys. Solids* **4,** p. 209, 1956.) D. R. Bland, England

1091. Whalley, E., The design of pressure vessels subjected to thermal stress. II. Steady state temperature distribution, *Canad. J. Technol.* **34,** 5, 291–303, Sept. 1956.

The analysis of part I is specialized to steady-state temperature distributions. D. R. Bland, England

1092. Barducci, I., On some characteristics of the phenomena of elastic relaxation in solids (in Italian), *Ric. sci.* **25,** 9, 2572–2585, Sept. 1955.

Only a few among the phenomena of elastic relaxation in solids lend themselves to a correct explanation by the elementary theory which admits only a single relaxation time; for the other phenomena it is necessary to admit the existence of more than one relaxation time. In the present note a systematic comparison between theoretical and experimental results has been attempted, showing how the pertinence of a phenomenon to one category or to the other can be clearly justified by the physical causes of the phenomenon and how the elementary theory can be modified so as to take into account all experimental facts.

From author's summary

1093. Habraken, L., and Greday, T., Modes of deformation of metals, *Rev. univ. Min.* (9) **12,** 8, 209–227, Aug. 1956.

1094. Akutowicz, F., Mechanical behavior of fibers, *J. Franklin Inst.* **261,** 5, 509–526, May 1956.

Paper presents a relatively new approach to the problem of describing viscoelasticity. Author considers viscoelasticity a phenomenon which is amenable to mathematical description. The problem is not considered or analyzed in terms of molecular theories nor is use made of the spring dashpot interpretation used in the past.

Paper is primarily concerned with theory as applied to textile fibers but the basic theory may also be applied to plastics and other viscoelastic materials. The description may be attacked by means of differential or integral equations, but the former is preferred. The differential equations are considered to be easier to construct, more amenable to numerical solution, and to give a clearer picture of the physical phenomena.

Author explains in detail the geometrical meaning of the differential equations and the space coordinates of force; elongation and time during cyclic loading are illustrated by descriptive geometric sketches. Finally, author describes an experiment with a special force-elongation-time apparatus, testing the validity of the theory when applied to tire-cord rayon. It is shown that virgin rayon when subjected to different loading cycles can not be described by a smooth equation.

Paper will be of interest to mathematicians concerned with viscoelasticity and will provoke comments from others who prefer the physical interpretation provided by springs and dashpots. Engineers who are accustomed to two-dimensional stress-strain curves will be interested in the attempts to describe time-dependent materials in a form which may eventually develop a psuedo Hooke's law. The method of attack is logical, straightforward, and rigorous. Although the experiment described resulted in a negative answer, the potentialities of this method of evaluation are great. The practical use of the theory remains to be demonstrated. R. H. Carey, USA

1095. Eakin, C. T., High temperature creep of coil springs, *Prod. Engng.* **27,** 12, 186–190, Nov. 1956.

1096. Jellinek, H. H. G., and Brill, R., Viscoelastic properties of ice, *J. appl. Phys.* **27,** 10, 1198–1209, Oct. 1956.

An apparatus has been constructed for the study of deformation under tension of single and polycrystalline ice. Deformations down to 10^{-5} cm could be measured. Deformation of single and polycrystals was investigated as a function of time, stress, and temperature. Whereas the strain rate for polycrystalline ice decreases with time, that for single glacier ice increases linearly with time. The deformation for fine-grained polycrystalline ice consists of an instantaneous elastic deformation, a transient creep, and a steady-state creep. Deformation curves can be represented by empirical equations. The recovery curves on removal of the loads have also been investigated, and the plastic flow has been deduced from the residual deformation after complete recovery. This plastic flow was found to be Newtonian within the range of stresses investigated, and the viscosity coefficients can be represented by an exponential relationship as follows: $\eta_1 = 7.5 \cdot e^{+16100/RT}$ poises, where 16 100 calories is the energy of activation for the plastic flow. The total deformation can be represented satisfactorily by a large number of Voigt units representing a distribution of retardation times, in series with a Maxwell unit.

The experimental results are further discussed in the light of current theories of dislocations, and tentative mechanisms for the deformation of single and polycrystalline ice are proposed.

From authors' summary

1097. Lu, H.-F., On volume visco-elastic theory of fluids and its application to sound dispersion phenomena, *Scientia Sinica* **5,** 1, 33–48, Mar. 1956.

A volume viscoelastic theory of fluids is applicable to all three kinds of relaxations—thermal, structural, and chemical. Applied to sound, it gives the Bourgin-Kneser equations for thermal relaxation and the Lieberman for chemical. It shows that the latter equation is valid only for liquids.

From author's summary by D. R. Bland, England

1098. McKinney, J. E., Edelman, S., and Marvin, R. S., Apparatus for the direct determination of the dynamic bulk modulus, *J. appl. Phys.* **27,** 5, 425–430, May 1956.

1099. Tchen, C.-M., Interfacial waves in viscoelastic media, *J. appl. Phys.* **27,** 5, 431–434, May 1956.

1100. Peterlin, A., and Copic, M., Gradient dependence of the intrinsic viscosity of linear macromolecules, *J. appl. Phys.* **27,** 5, 434–438, May 1956.

1101. Akutowicz, F., Mechanical behavior of viscoelastic fibers, *J. appl. Phys.* **27,** 5, 439–441, May 1956.

1102. Truesdell, C., Hypo-elastic shear, *J. appl. Phys.* **27,** 5, 441–447, May 1956.

1103. Nielsen, L. E., and Stockton, F. D., Flow patterns in glacier ice, *J. appl. Phys.* **27,** 5, 448–453, May 1956.

1104. Tordella, J. P., Fracture in the extrusion of amorphous polymers through capillaries, *J. appl. Phys.* **27,** 5, 454–458, May 1956.

1105. Biot, M. A., Theory of deformation of a porous viscoelastic anisotropic solid, *J. appl. Phys.* **27,** 5, 459–467, May 1956.

1106. Myers, R. R., Miller, J. C., and Zettlemoyer, A. C., Viscometric analysis of dispersions at small shear stresses, *J. appl. Phys.* **27,** 5, 468–471, May 1956.

Failure, Mechanics of Solid State

(See also Revs. 1019, 1042, 1071, 1092, 1115, 1229)

1107. Soete, W., Brittle fracture and resistance along the thickness of the steels (in French), *Rev. Métall.* **51,** 12, 813–823, Dec. 1954.

Author investigates the longitudinal splits occurring in notched plates under tensile or bending loads. The existence of the splits, observed on ductile steels only, is a sign of mechanical anisotropy of the steel and of stress perpendicular to the rolling plane of the plate. According to the experiments of author on plates (thickness 25 mm), the ratio of resistance to fracture along the rolling direction and of resistance along the thickness of plate is 1.5–3. From the investigation author concludes the following: The temperature of transition from ductile to brittle fracture is decreased by diminution of the strength along the thickness of plate. H. Mussman, Germany

1108. Deck, W., Crack detection in aircraft structures, *J. roy. aero. Soc.* **60,** 551, 739–748, Nov. 1956.

1109. Kariakin, A. V., Using fluorescent flaw detection in the preventive maintenance of steam turbines (in Russian), *Teploenergetika* **3,** 3, 54–55, Mar. 1956.

1110. McEvily, A. J., Jr., Illg, W., and Hardrath, H. F., Static strength of aluminum-alloy specimens containing fatigue cracks, *NACA TN* 3816, 54 pp., Oct. 1956.

Seven configurations of specimens made of 2024 and 7075 aluminum alloys in both rolled and extruded form were subjected to repeated axial loads until fatigue cracks of various lengths were formed. The specimens were then subjected to static tests to determine the residual static strength. Small cracks resulted in disproportionately large reductions of static strength, the reduction being greater for 7075 than for 2024 aluminum alloy. A simple method of analysis which predicts the observed results is developed and described.

From authors' summary by P. E. Sandorff, USA

1111. Whaley, R. E., McGuigan, M. J., and Bryan, D. F., Fatigue-crack-propagation and residual-static-strength results on full-scale transport-airplane wings, *NACA TN* 3847, 57 pp., Dec. 1956.

Results are presented of fatigue-crack-propagation studies conducted during fatigue tests of nine complete wings from C-46 airplanes. Also presented are the results of static tests of these wings with fatigue failures of various extents.

In general the cracks grew at a slow, fairly uniform rate during a large portion of the fatigue life until a certain critical percentage of the structure had failed, after which the cracks grew rapidly. This critical percentage was found to vary inversely with the load level. The portion of the fatigue life during which the crack was present and growing also varied in the same manner.

Another constant-level test on one outer panel with a machined notch in the 30%-chord spar also produced a propagation curve similar in shape to all the other propagation curves.

The static tests of partially failed wings indicated that the strength of the tension surface was considerably less than the calculated strength obtained from consideration of the amount of material that failed. In spite of this strength reduction in the tension surface, the resistance of the wing to the bending loads to be expected in flight was very good even with large failures present. This condition occurred because, in order to have adequate strength for the negative design load, the lower surface had excess strength for the positive design load.

The reduction in strength of the tension surface varied with the amount of material failed and was independent of the particular elements involved in the area that failed in fatigue. This strength reduction was found to compare favorably with the results of similar tests on small monoblock specimens.

From authors' summary

1112. Forrest, P. G., The measurement of fatigue damage in mild steel, *Engineering* **182,** 4721, 266–268, Aug. 1956.

The purpose of the investigation is to find whether the measurement of fracture stress after given amounts of fatigue stressing would indicate progressive damage or the rate of crack propagation during fatigue of mild steel. Unnotched and notched test pieces of mild steel were tested in a direct-stress fatigue machine. Some of the tests were run to fracture, while others were stopped after a certain number of cycles and tested to failure in static tension at −196 C. From author's summary

1113. Maschmeyer, A. H., Wear life of aluminum gears, *Prod. Engng.* **27,** 9, 160–166, Sept. 1956.

Development of analytical procedure for estimating probable life of aluminum gears is described. Modification of Hertz's theoretical equations to conform to actual test results and comparison of anodized and unanodized gears are discussed.

From author's summary

1114. Paul, B., Graphical solutions for two failure theories, *Prod. Engng.* **27,** 3, 178–181, Mar. 1956.

Of the many theories of elastic failure that have been proposed, two have real practical significance. But even these are usually cumbersome to use. The graphical methods shown here have been developed to facilitate the solution of problems in predicting elastic failure. From author's summary

Material Test Techniques

(See also Revs. 1098, 1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1124)

1115. Aughtie, F., and Cox, H. L., An unconventional type of fatigue-testing machine, *Aero. Res. Counc. Lond. Rep. Mem.* 2833, 12 pp., 1955.

The advantages of resonant-type machines are discussed and effects of specimen stiffness are appraised mathematically. Problems of starting and of maintaining stable operation are solved by use of a slipping-clutch mechanism to excite the vibration. Construction of axial or torsional machines for large loads at high speeds is feasible by these methods with only small energy input.

T. J. Dolan, USA

1116. Illg, W., Fatigue tests on notched and unnotched sheet specimens of 2024-T3 and 7075-T6 aluminum alloys and of SAE 4130 steel with special consideration of the life range from 2 to 10,000 cycles, *NACA TN* 3866, 40 pp., Dec. 1956.

Fatigue tests were performed on notched and unnotched sheet specimens made of 2024-T3 and 7075-T6 aluminum alloys and of SAE 4130 steel. The steel was tested in two conditions: normalized and heat-treated to a tensile strength of 180 ksi. The notched specimens had theoretical stress-concentration factors of 2.0 and 4.0 and the mean loads were 0 and 20 or 50 ksi. Emphasis is placed on the life range from 2 to 10,000 cycles. Some previously published data are included to extend the data to lifetimes up to 10^8 cycles. It was found that repeated applications of stresses in the vicinity of the ultimate strength on notched and unnotched specimens produced failures in much smaller numbers of cycles than might be inferred from previously published data. Ratios of fatigue strengths of unnotched specimens to those of notched specimens are given. From author's summary

1117. Davies, R. B., and Mann, J. Y., The changes in hardness during fatigue tests on copper at 6000 cycles/min, *Aero. Res. consult. Comm. aero. Res. Lab. Melbourne, Austral. Rep.* Met. 16, 11 pp. + 4 figs., May 1956.

Annealed copper specimens, subjected to rotating cantilever fatigue tests at 6000 cpm, increased in hardness during the early stages of tests at a rate depending upon the magnitude of the applied stress. However, the hardness of specimens tested under widely different stresses tended to converge toward a common range as cycling proceeded, and this hardness was much lower than the maximum hardness developed in a similar specimen fractured in static tension.

Possible explanations of the observed hardness variations are discussed.

Some observations of the development of cracks at early stages of fatigue tests are presented. From authors' summary

Mechanical Properties of Specific Materials

(See also Revs. 1026, 1059, 1101, 1112, 1113, 1116, 1117, 1229, 1273, 1278)

1118. Guard, R. W., Metals at elevated temperatures, *Prod. Engng.* **27,** 10, 160–164, Oct. 1956.

Metals show the same general behavior at similar homologous temperatures (*absolute service temperature/absolute melting temperature*) even though their melting points are very different. Softening of cold-rolled commercially pure metals takes place at a homologous temperature of about 0.35. Alloying generally shifts the softening to higher homologous temperatures. Above 0.35 on the homologous scale, time becomes important because of creep, aging, recovery, or recrystallization.

The thermal conductivity, thermal expansion, and dynamic elastic modulus are temperature dependent but not necessarily time dependent. These properties determine the thermal stress originating from nonuniform or fluctuating temperatures.

The trend is to higher temperatures in power applications. This results in widespread interest in high-melting metals and ceramics.

M. Manjoine, USA

1119. Muir, H., A new approach to the properties of steels in engineering, *J. Instn. Engrs. Austral.* **28,** 6, 161–168, June 1956.

Recent work by the author and associates has shown that a hitherto neglected strength parameter—namely, the elastic limit—can be measured reproducibly by a load-unload method, using resistance strain gages. The high sensitivity of the method has made it possible to distinguish the stress value at which the first 1 to 2×10^{-6} permanent strain appears, and there is evidence that the elastic limit defined in this way is not merely a flow stress parameter of the "proof stress" type, but has real physical significance in terms of the elastic-to-plastic transition. In particular, repetition of any load just below the defined limit produces no permanent strain, while repeated loads of higher value produce a small strain increment at each load cycle. On this basis a correlation between the elastic and fatigue limits was anticipated and later demonstrated by experiment.

A comparison has been made of the effect of heat treatment and composition variables on the elastic limit and on the conventional tensile test parameters such as yield and ultimate strengths, etc. The results show that the dependence of the elastic limit on tempering temperature for hardened steels differs greatly from that observed for the conventional properties, particularly in the region of low tempering temperature and in the "500F brittleness" region. Thus the elastic limit has its minimum value in the fully hardened steel and rises with increasing tempering temperature to a maximum in the 500R range of tempering temperature (250C and vicinity), while yield and ultimate strengths decrease almost continuously with tempering temperature.

At high tempering temperatures the elastic limit and the stress-strain curve in its vicinity were found to be markedly sensitive to rate of cooling from the tempering treatment. This suggests a possible correlation with temper brittleness phenomena, and further investigation of the effect is under way.

On the basis of these results, and in view of known inadequacies of the conventional strength parameters, a case can be made for the application of elastic limit data in engineering design, particularly at high hardness levels, and where fatigue and brittleness problems are likely.

Reviewer believes this method to be particularly valuable for accurate design for exact fatigue strength, such as in aircraft, and suggests that a similar method is needed for aluminum testing.

A. S. Andes, USA

1120. Hughes, D. S., and Maurette, C., Dynamic elastic moduli of iron, aluminum, and fused quartz, *J. appl. Phys.* **27,** 10, 1184–1186, Oct. 1956.

The dynamic elastic constants of Armco iron, pure aluminum, and fused quartz have been measured with a supersonic pulse technique as functions of pressure and temperature over the range 1 to 9000 bars and 25C to 300C (200C for quartz).

Within the experimental accuracy the dynamic elastic moduli of these materials can be represented by linear functions of pressure and temperature.

The isothermal bulk moduli of other observers have been used to compute the equivalent adiabatic moduli by use of the thermodynamic relations. Comparison shows that at high pressures the dynamic moduli agree with the adiabatic moduli within the experimental accuracy for iron and aluminum. At low pressure the dynamic modulus of Armco iron is less than the adiabatic. The deviation is small but is about four times the estimated probable error. From authors' summary

1121. Hyam, E. D., and Nutting, J., The tempering of plain carbon steels, *J. Iron Steel Inst. Lond.* **184,** part 2, 148–165, Oct. 1956.

Electron metallographic techniques have been used to follow the changes in microstructure resulting from tempering four plain carbon steels in the temperature range 500–700C. The carbide particle-size distributions have been obtained and from these results it has been possible to calculate the changes of individual particle diameters during the progress of tempering.

The progress of tempering has also been followed by taking hardness measurements, and from these it has been possible to calculate the activation energy of the softening process. The values obtained were $\simeq$ 60 kcal/g-mol and it is concluded that softening is controlled by a mechanism involving the self-diffusion of iron.

The various relationships which have been proposed between parameters of the microstructure and hardness are discussed and compared with the present results. It is concluded that none of the previously established relationships accounts satisfactorily for the changes in steels during tempering.

A new mechanism is proposed for tempering. It is suggested that the hardness of tempered steels depends upon the ferrite grain size—the larger the grains, the softer the steel. The growth of the ferrite grains is limited by the carbide particles which are present at the ferrite grain boundaries; therefore, during tempering, as the carbide particles grow, so the ferrite grains can grow and the steel becomes softer.

This mechanism is supported by the fact that a linear relationship has been observed between the hardness and the reciprocal of the square root of the ferrite grain diameter.

From authors' summary

1122. Gemmill, M. G., Hughes, H., Murray, J. D., Pickering, F. B., and Andrews, K. W., Study of 7% and 8% chromium creep-resisting steels for use in steam power plant, *J. Iron Steel Inst. Lond.* **184,** part 2, 122–144, Oct. 1956.

The study of 7%- and 8%-chromium creep-resisting steels to bridge the gap at present existing between available low-alloy and austenitic materials used in steam power plant was the objective of the research work reported in this paper. Study is divided into three parts. The first is concerned with the preliminary development work on various 7%-Cr-base steels of duplex constitution. The second details the results of a systematic study of the metallurgical characteristics of various 8%-Cr, 3%-Mo steels, ferritic at all temperatures. In the third part the properties of an 8%-Cr-Mo-Ti steel selected from the foregoing systematic study are outlined in relation to those of 2¼%-Cr-Mo ferritic, and 18/12/1 austenitic creep-resisting steels.

From authors' summary

1123. Fauconnier, M., The plasticity of mild steel as a safety factor (in French), *Publ. Int. Assn. Bridge struct. Engng.* **15,** 69–82, 1955.

The plasticity of mild steel forms a safety factor for steel structures. Paper has for its principal objective the making of constructional engineers more familiar with this consideration than they appear to have been hitherto.

Author mentions the example of a Paris bridge which, while in use, was subjected to considerable accidental deformation, without thereby losing its capacity to carry the applied loading.

He then explicitly reports a test demonstration which clearly reveals the phenomenon of adaptation. For this he used a steel bar set up on three simple supports, under two concentrated, increasing, loads. The alteration of the bending moments as a function of these loads was rigorously followed through, and from this there could be demonstrated an increasing agreement between the support- and panel-moments with increasing load.

Moreover, the appended photos of the work show the photoelastic picture of the cross section at the supports, during the course of the experiment, wherein the progress of the plastic deformation with increasing loading is clearly apparent.

In conclusion, author advocates the proposition that there will continue to be a possibility of steel being inefficiently used so long as its plastic capacity is disregarded, and he hopes that future standards will be conditioned by these facts.

From author's summary

1124. Casse M., Comparative tension and bending tests on steel specimens with drilled or punched holes, and holes that have been subpunched and drilled (in French), *Inter. Assn. Bridge Struct. Engng.* **15,** 31–50, 1955.

Investigations are described which were carried out by the S.N.C.F. on steel specimens, in which tests were made with drilled, punched, or subpunched and drilled holes.

The disadvantage of the punched holes is clearly shown, especially in the bending tests, while the punched holes which are drilled out by 3 mm (⅛ inch) are not inferior to the drilled holes.

From author's summary

1125. Clark, M. E., Corten, H. T., and Sidebottom, O. M., Inelastic behavior of ductile members under dead loading, *Univ. Ill. Engng. Exp. Sta. Bull.* no. 426, 48 pp., 1954.

The purpose of this study was to investigate the time effects associated with dead-load testing of steel and aluminum members. In the inelastic range, each load was maintained until inelastic deformation ceased at that load. The test members included four straight mild-steel beams of various cross sections, three curved mild-steel beams of various cross sections, one straight rail steel (0.8% carbon) rectangular beam, and one straight aluminum alloy 24S-T rectangular beam. In most cases, test results are also presented for beams subjected to short-time tests, i.e., tests conducted in screw- or hydraulic-powered testing machines. A comparison is made between the test data for the dead-load tests, the test data for the short-time tests, and the theoretical relations.

From authors' summary

1126. Toaz, M. W., and Ripling, E. J., Correlation of the tensile properties of pure magnesium and four commercial alloys with their mode of fracturing, *J. Metals* **8,** 8, 936–946, Aug. 1956.

Tensile tests were conducted on pure magnesium and on four commercial alloys over a variety of temperatures and strain rates. The high positive slope of the ductility versus testing temperature curves that is found over a short range of testing temperatures for these materials was shown to result from the fact that the microstructure was not stable at these testing temperatures. Pure magnesium did not display a transition temperature, although its sub-room-temperature ductility was low. This poor ductility resulted from a grain boundary weakness. The aluminum-bearing commercial magnesium alloys had a higher ductility than the pure magnesium. These alloys did exhibit a transition temperature and grain boundaries that were stronger than the grain material. Both pure magnesium and the commercial alloys began initiating cracks at strains equal to one half of their fracture strain.

From authors' summary

1127. Gibbs, T. W., Tensile properties of HK31XA-H24 magnesium-alloy sheet under rapid-heating conditions and constant elevated temperatures, *NACA TN* 3742, 20 pp., Aug. 1956.

Specimens of HK31XA-H24 magnesium-alloy sheet from an experimental batch were heated to failure at nominal temperature rates from 0.2F to 100F per second under constant-load conditions. Rapid-heating yield and rupture stresses are presented and compared with the yield and ultimate stresses from elevated-temperature tensile stress-strain tests for ½-hour exposure. Linear temperature-rate parameters were used to correlate rapid-heating results by constructing master curves which can be used for predicting yield stresses and temperatures and for estimating rupture stresses and temperatures.

From author's summary

1128. Ewing, J. F., and Freeman, J. W., Influence of hot-working conditions on high-temperature properties of a heat-resistant alloy, *NACA TN* 3727, 134 pp., Aug. 1956.

The relationships between conditions of hot-working and properties at high temperatures and the influence of the hot-working on response to heat treatment were investigated for an alloy containing nominally 20% chromium, 20% nickel, 20% cobalt, 3% molybdenum, 2% tungsten, and 1% columbium. Commercially produced bar stock was solution treated at 2,200F to minimize prior history effects and then rolled at temperatures of 2,200, 2,100, 2,000, 1,800, and 1,600F. Working was carried out at constant temperature and with incremental decreases in temperature simulating a falling temperature during hot-working. In addition, a few special repeated cyclic conditions involving a small reduction at a high temperature followed by a small reduction at a low temperature were used to study the possibility of inducing very low strengths by the extensive precipitation accompanying such procedures. Most of the rolling was done in open passes with a few check tests being made with closed passes. Reductions up to 40% were used, with some conditions carried to as high as 65%. Heat treatments at both 2,050 and 2,200F subsequent to working were used to study the influence on response to heat treatment.

The evaluation of the effects of rolling was based on rupture tests at 1,200 and 1,500F, on creep rates during the rupture tests, and on creep rates for stresses of 25,000 psi at 1,200F and 8,000 psi at 1,500F. Hardness, microstructures, and lattice-parameter measurements were used to obtain data explaining the metallurgical factors responsible for the observed effects on properties at high temperatures.

From authors' summary

1129. Zelger, C., A new method for the determination of the tensile strength of concrete (in German), *Beton u. Stahlbeton.* **51,** 6, 139–140, June 1956.

Author discusses simple test used in South America and Japan for some time. Test consists of loading standard test cylinder in compression along diametrically opposite generatrices. Stress normal to plane of loading is a tensile stress, which is constant over most of this area. Stress is of sufficient magnitude to cause tensile failure. Test is simpler than standard compressive test since no preparation of specimen is necessary. Test should prove especially useful in highway and airstrip construction.

F. J. Mehringer, USA

1130. Scharf, W., New way of heating net-work construction, using asbestos-concrete pipes (in Polish), *Przeglad Techn.* **75,** 11, 402–405, Nov. 1954.

This is a detailed description of the construction of heating net-work applied recently in Czechoslovakia, where asbestos-concrete pipes are used instead of steel-concrete channels.

M. Z. Krzywoblocki, USA

1131. Gates, G. H., and Larson, W. M., Polyurethane rubber as a material of construction, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-55, 3 pp.

Higher stress capacity than natural rubber creates wide application possibilities for polyurethane.

From authors' summary

1132. Miller, K. D., Jr., and Breslau, S. M., Fiberglas-reinforced plastic as a rocket structural material, *Jet Propulsion* **26,** 11, 969–972, Nov. 1956.

Authors describe application of Fiberglas-reinforced plastic to rocket cases which are essentially highly stressed pressure vessels. Methods for constructing rocket cases are discussed. Strength-weight ratio of this composite material is very high, exceeding that of many structural metals and implying potential weight saving. Other advantages of the Fiberglas-reinforced plastic as well as some disadvantages are cited.

B. M. Axilrod, USA

1133. Warriner, W. C., and Cheney, A. J., "Zytel" nylon resin, a versatile engineering material, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-70, 22 pp. + 11 figs. + 9 tables.

This paper outlines the availability of design data, the outstanding and unusual properties of "Zytel," and how they can be applied by the practical designer.

From authors' summary

1134. Kotorski, Z., Possibilities of exploitation of saw dust in building materials (in Polish), *Przeglad Techn.* **76,** 4, 137–141, Apr. 1955.

Writer emphasizes that it is possible to use saw dust for production of bricks and similar building materials, but that the problem is in its infancy. He mentions that in Poland there are buildings constructed with the use of saw-dust-limestone bricks.

M. Z. Krzywoblocki, USA

Plasticity, Forming and Cutting

(See also Revs. 979, 1104)

Book—1135. Mittag, C., Method for the determination of highest output of ball and tube mills [Prufverfahren zur ermittlung Hochstleistungen in Kugel- und Rohrmuhlen], Berlin, Springer-Verlag, 1954, iv + 41 pp. DM 6.

In operating modern grinding mills, the energy losses are about 99.5%. As the necessity for greater output is always present, the mills are built in larger size. It is of particular importance in the use of large mills to formulate methods for evaluating the factors which determine the energy consumption.

The "specific grinding resistance" gives a survey of the resistance, which increases during grinding the material finer and finer. This is a new concept and it will find more consideration in future. We can translate the results of the experiments made with a laboratory tube mill to industrial mills, if the diameter of the laboratory mill is not under 800 mm.

The booklet describes how to arrive at the "specific grinding resistance," how to make the experiments, and how to evaluate the results. It elaborates with examples.

F. Hinsenkamp, Hungary

1136. Johnson, W., Extrusion through wedged-shaped dies, Part I, II, *J. Mech. Phys. Solids* **3,** 3, 218–230, Apr. 1955.

Results of calculations of the steady-state pressure for the direct extrusion of sheet under plane strain conditions through square and wedge-shaped dies are given. Results depend upon whether a dead metal zone is formed on the die face or whether the metal slips over the die face. From author's summary

1137. Wallace, J. F., The scale effect in the cup drawing test, *J. Iron Steel Inst. Lond.* **184,** part 2, 144–148, Oct. 1956.

The specification of the drawing performance of sheet metals by the cup drawing test is discussed with particular reference to cup diameter, sheet thickness, and blankholder load. Experimental results from cups 1 in., 1⅜ in., 2 in., and 4 in. diam drawing from sheet thicknesses of 0.012 in., 0.018 in., 0.024 in., 0.036 in., and 0.048 in., show a decrease in limiting drawing ratio with increase of punch diameter and decrease of sheet thickness. Similar limiting drawing ratios for different thicknesses are obtained with the tool geometry in proportion to thickness.

It is suggested that a ¾-in.-diam cup should be used for tests on sheet 0.012–0.016 in. thick and a 2-in.-diam cup for 0.030–0.040 in. thick, although, with nongeometric tools, similar performance to the smaller cup on thin materials can be obtained from the 2-in. cup. From author's summary

Hydraulics; Cavitation; Transport

(See also Revs. 1205, 1216)

1138. Kindsvater, C. E., and Carter, R. W., Tranquil flow through open-channel constrictions, *Trans. Amer. Soc. civ. Engrs.* **120,** 955–992, 1955.

Authors develop a method for computing stream discharge from measured differences in local surface elevation at an abrupt lateral contraction. Model experiments are reported covering a wide variation of significant flow and geometric properties corresponding to actual flows through bridge water-ways. Using this experimental data, the effects of these variables are systematically separated and a simple procedure is developed for discharge calculations from field measurements. The method should be especially useful for determining peak discharges from flood marks. J. S. Holdhusen, USA

1139. Tracy, H. J., and Carter, R. W., Backwater effects of open-channel constrictions, *Trans. Amer. Soc. civ. Engrs.* **120,** 993–1018, 1955.

As an extension of investigations reported in preceding review, a procedure is developed for computing the difference in level between the normal and backwater profiles at a section immediately upstream of an open-channel constriction. Again, systematic model experiments (in a longer flume) are used to determine the effects of boundary shapes and channel roughness encountered in actual bridge waterways. The method can be used to more accurately determine bridge clearance necessary to avoid flood damage. J. S. Holdhusen, USA

1140. Prusov, V. M., Exact integration of equation for unsteady slow varying movement of liquid in some parabolic channels (in Russian), *Uch. Zap. Karelo-Finskogo Univ.* **3,** 4, 63–76, 1954; Rev. 198, *Ref. Zh. Mekh.*, 1956.

Exact solution is obtained of differential equations for unsteady slow varying movement in channels with cross section limited by parabolas of power $k = 2/(2m - 1)$, where $m = 1, 2, \ldots$, neglecting resistance forces. Author takes equations from a monograph by S. A. Khristianovich (in a symposium "Some new problems of a compact medium mechanics," 1938, Academy of Sciences, USSR) and applies integration method of similar equations for one-dimensional movement of compressible gas [see Landau, L. D., and Lifshits, E. M., "Mechanics of compact medium," 1954, Gostekhizdat]. This method, based on Legendre transformation, is adapted to solution of a partial problem: unsteady flow is studied in a half-parabolic channel, limited by parabola $y = ax^2$; channel is divided by a thin vertical wall, eliminated at start; the upstream reach is of limited length.

Courtesy of Referativnyi
Translated by S. Kolupaila, USA. V. A. Karpychev, USSR

1141. Fandeiev, V. V., Particularity of a formula for critical slope (in Russian), *Nauk Zap. Moskovskogo Inst. Vodnogo Khoziaistva* **18,** 53–68, 1955; Rev. 200, *Ref. Zh. Mekh.*, 1956.

Relationships of a critical slope in trapezoidal (including rectangular and triangular) and circular channels are completely treated. The Chezy factor is applied in an exponential from according to N. N. Pavlovskiĭ's formula. Tables and diagrams are

given for critical slopes; relationship between critical slope and Froude number is shown. Practical instructions are given for application to spillways with critical slope, and examples of computation are added.

Courtesy of Referativnyi Zhurnal.
Translated by S. Kolupaila, USA. G. K. Mikhailov, USSR

1142. Ibad-Zade, Yu. A., Cross-section development of a natural channel (in Russian), *Trudi Energet. Inst. im. I. G. Es'mana, Akad. Nauk Azerbaidzhan. SSR*, no. 12, 173–193, 1954; Rev. 201, *Ref. Zh. Mekh.*, 1956.

Detailed results of a previous study concerning geometrical elements of channels (area, wetted perimeter, hydraulic radius, surface width, best hydraulic section) similar in form to the contour of elastic thread under hydraulic pressure. Comparative computations are included.

Courtesy of Referativnyĭ Zhurnal.
Translated by S. Kolupaila, USA. G. K. Mikhailov, USSR

1143. Lobaiev, B. N., New formulas for pipes in a transition zone. Symposium on "News in construction." Sanitarnaïa Tekhnika, Academy of Architecture, Ukrainian SSR, Kiev, 1954, pp. 5–10; Rev. 1465, *Ref. Zh. Mekh.*, 1956.

Author offers an empirical formula $f = 1.42/(\log Rd/K)^2$ for the friction coefficient for turbulent flow in a transition zone between hydraulically smooth and fully rough friction. Formula was derived from experiments by G. A. Murin (1948). Author proves that, for values of d/K between 100 and 10,000, this formula gives results very close to the universal formulas by Colebrook (1939) and Altshul (1952). Nomograms are added for easy reading of friction coefficients.

Author also gives two approximate formulas for the region of fully rough pipes:

$f = 0.150\ (K/d)^{0.3}$ when $2K/d$ is between 1/40 and 1/500
$f = 0.076\ (K/d)^{0.2}$ when $2K/d$ is between 1/500 and 1/10,000

Author states that these formulas differ less than 1% from the known formula by Prandtl-Nikuradse for rough pipes.

Courtesy of Referativnyĭ Zhurnal.
Translated by S. Kolupaila, USA. A. D. Altschul, USSR

1144. Toch, A., Discharge characteristics of tainter gates, *Trans. Amer. Soc. civ. Engrs.* **120,** 290–300, 1955.

It is of great interest to have related to the geometrical parameters of tainter gates, the different characteristics of free flow and submerged flow. The hydrodynamic problem is much complicated indeed by the curvature of the flow.

Extending Metzler's experiments and by varying the trunnion height, the author empirically determines the variations of the coefficient of contraction as a function of the lip angle θ of the gate, which permits him further to find a direct ratio between the discharge coefficient and the coefficient of contraction. Besides, we can notice that the influence of the parameter a/r (a trunnion height; r radius of the gate) is related to that of the lip angle θ. Reviewer made a detailed study of the flow under a sliding gate in the publication: "Etude de quelques écoulements comportant la formation d'une veine de courant." In the thesis he has recently been preparing in the Hydraulics Laboratory of Toulouse, Mr. Panikar determined the characteristics of the flow in a spillway equipped with a tainter gate. L. Escande, France

1145. Ball, J. W., Cavitation characteristics of gate valves and globe valves used as flow regulators under heads up to about 125 ft, ASME Fall Meet., Denver, Colo., Sept. 1956. Pap. 56-F-10, 10 pp.

Using high pressure for irrigation-distribution systems the free-flow release directly downstream of the valves is unsuitable because of the wide dispersion of the jets in the case of partial openings. Confining the jets below the valves into pipe lines involved certain problems, especially cavitation ones. Author discussed series of tests made in order to clarify these questions. A cavitation number ("cavitation index") was introduced to analyze the cavitation characteristics. A sudden enlargement in the pipe sections immediately downstream was introduced with a view to reducing the cavitation tendency or to eliminating cavitation damage below gate valves, respectively.

A protection with rubber-like products in the pipe wall against cavitation erosion was considered favorable only in cases of mild cavitation. Venting the area at the top of the pipe just behind the valves was also not considered reliable.

The results of this investigation and several graphs in the paper represent a very valuable help for those problems and projects.

P. Franke, Germany

1146. Hacker, P. T., Saper, P. G., and Kadow, C. F., Impingement of droplets in 60° elbows with potential flow, *NACA TN* 3770, 54 pp., Oct. 1956.

Trajectories were determined for water-droplet particles in air flowing through 60° elbows especially designed for two-dimensional potential motion. The elbows were established by selecting as walls of each elbow two streamlines of a flow field produced by a complex-potential function that established a two-dimensional flow around a 60° bend. An unlimited number of elbows with slightly different shapes can be established by selecting different pairs of streamlines as walls. The elbows produced by the complex potential function are suitable for use in aircraft air-inlet ducts. These elbows should have lower pressure losses than bends of constant cross-sectional area. The droplet impingement data derived from the trajectories are presented along with equations, so that collection efficiency, area, rate, and distribution of droplet impingement can be determined for any elbow defined by any pair of streamlines within a portion of the flow field established by the complex potential function.

From authors' summary by L. J. Tison, Belgium

Incompressible Flow: Laminar; Viscous

(See also Revs. 1145, 1164, 1193, 1202, 1216)

1147. Schmieden, C., and Muller, K.-H., The flow of a line source in the semi-space; an exact solution of the Navier-Stokes equations (in German), *Z. Flugwiss.* **4,** 9, 300–309, Sept. 1956.

Exact solutions of the Navier-Stokes equations for incompressible flow are presented. The solutions satisfy axisymmetrical conditions which are of considerable physical interest as follows: the velocity is zero on an infinite plane (xy plane) and the velocities in the neighborhood of the z axis (perpendicular to the xy plane) are given by a constant line-source or sink. Far away from the xy plane, the solution is asymptotic to the axisymmetrical source flow in absence of viscosity.

The partial differential equation for the Stokes' stream function is reduced to a fourth-order total differential equation by separation of variables. This differential equation is integrated exactly, leading to several particular solutions, including sources of any strength and sinks of strength to kinematic viscosity ratios < 2. This does not mean that solutions with this ratio > 2 do not exist, since the presented solutions are not necessarily complete.

For each solution the velocity gradient $\partial u/\partial n$ (u velocity, n direction z) on the xy plane is a constant; but $\partial u/\partial n$ assumes, according to the source strength, positive, zero, (separation), and negative (backflow) values. The solution is simplest for $\partial u/\partial n = 0$.

Solutions with flow along the z axis are also given. In these cases, any sink strength is possible, and for any given source strength infinitely many solutions are possible, each with a fixed velocity gradient $\partial u/\partial n$ on the xy plane.

Reviewer feels that further considerations of the presented solutions will give valuable contributions to the knowledge of laminar

boundary-layer theory; e.g., it may serve as a check of the validity of boundary-layer assumptions.

H. P. Eichenberger, USA

1148. Eckert, E. R. G., and Irvine, T. F., Jr., Flow in corners of passages with noncircular cross sections, *Trans. ASME* **78,** 4, 709–718, May 1956.

Paper covers an excellent and thorough investigation of flow characteristics through triangular shaped passages. Flow visualizations indicate that at low Reynolds numbers the entire flow is laminar, while over a large range of intermediate Reynolds numbers laminar flow persists in the apex region of the triangle with a gradual change to turbulent flow near the base of the triangular section. This lateral transition occurs considerably closer to the apex than velocity profile slopes indicate. As should be expected, the extent of the laminar cross-section region decreases with higher mean Reynolds numbers and with larger apex angles. Pressure gradient measurements indicate that, in this intermediate Reynolds number range, fully developed pipe flow may not be achieved within a length of 70 hydraulic diameters. In the laminar flow region excellent agreement is found between experiment and theoretical predictions.

Authors point out the value of such a study as background for heat-transfer work in noncircular passages, where local hot spots in the corner regions due to extended laminar flow may limit the heat-exchanger design.

The range of variables investigated, the care and thoroughness of the experimentation, and the method of approach used make this an outstanding paper. F. Landis, USA

1149. Pode, L., The formulation of potential flow problems in terms of a Fredholm integral equation of the second kind and integral equation methods for conformal mapping, *David W. Taylor Mod. Basin Rep.* 939, 47 pp., Mar. 1956.

This paper of partly expository character discusses the solution of two-dimensional obstacle-flow problems by *vortex-distributions* in terms of integral equations (I.E.) of the second kind. The basic derivations of the I.E. comprise also the representation of the flow field by a *source distribution* over the obstacle boundary. The construction of a conformal map is discussed in connection with the solution of the I.E. of purely circulatory flow. Discussion of the convergence of successive approximations follows.

Reviewer finds that author has successfully presented a topic which in the standard texts on potential theory is relegated to an insignificant appendix of the general theory. The mathematical level is such as to make it readily accessible to engineers, and the applicability of numerical methods is taken into account. One or two insignificant errors are easily recognized.

G. Kuerti, USA

1150. Fadnis, B. S., Axisymmetric flow in perfect fluid—II, *Bull. Calcutta math. Soc.* **47,** 4, 249–254, Dec. 1955.

Paper presents stream functions for motion of a perfect fluid past a paraboloid of revolution. Fluid is assumed to have a motion at infinity composed of a constant velocity and a uniform angular velocity with axis parallel to the direction of uniform flow. Additional boundary condition of no slipping of the fluid on the surface of the body is used to yield a unique solution. A technique for evaluating constants of solution is indicated.

T. E. Caywood, USA

1151. Popov, M., Investigation of an injection nozzle having a variable spray cone angle, *Annuaire de l' Ecole Polytechnique d'Etat.* 1953, Sofia, Bulgaria, 1–28.

The purpose of this investigation was to develop an injection nozzle for internal combustion engines which would produce a spray, the cone angle of which would vary during the injection, in order to obtain a thorough mixing of the liquid droplets with the combustion air.

The patent specification DRP no. 532013 (1924) for Aero A.-G. Kussracht (Switzerland) describes a pintle-type nozzle, with a specially formed pintle tip. The latter coacts with the nozzle orifice in such a manner that at varying needle lift the spray angle also varies. However, in actual operation the needle opens and closes rapidly; therefore during most of the injection the same spray angle will prevail. The equation of motion of the needle is investigated, and the question is posed whether a slowing down of the needle lift could be achieved by either: a) increasing the mass of the needle and of the adjoining valve elements, or b) by introducing a hydraulic damping. Both of these methods are investigated analytically, and it is concluded that only the method (b) is practicable. An experimental nozzle has been devised, incorporating hydraulic damping. The variation of the spray angle during the period of injection has been photographically determined by means of an optical arrangement devised by the author. While the experimental nozzle performs qualitatively in the intended manner, yet it needs further improvement—according to the author—in order to make it practically usable. K. J. DeJuhasz, USA

1152. Magarvey, R. H., and Taylor, B. W., Apparatus for the production of large water drops, *Rev. sci. Instrum.* **27,** 11, 944–947, Nov. 1956.

Drop generators are described for the production of streams of drops the equivalent diameters of which are between 0.5 and 20 mm. The generators are based on the principle of the interrupted jet as described by Lord Rayleigh, who found that the kind of disturbance that produced the greatest regularity in resolution was one which impressed upon the jet undulations of length approximately 4½ times the diameter. Two types of droppers based on this principle are described. In one an oscillator-driven earphone is used as the vibrating unit, in conjunction with hypodermic needles of 0.5 to 1.5-mm inside diam, yielding drops of 0.3 to 2.5-mm diam at a maximum production rate of about 400/sec. In the other, a spring-loaded plunger driven by a motor equipped with variable-speed drive is the source of vibrations; discharge tubes of 7 to 12-mm diam are used, yielding drops up to 15-mm diam, at a rate of up to 20/sec.

Advantages and disadvantages of drop production by these methods are discussed, and data given showing a high degree of uniformity of drop size. Accurate size control and size determination are discussed relative to the execution of experiments designed to measure the physical properties of drops during free fall. In order to study the instability and breakup of large drops, reasonably well-formed drops are produced with large equivalent diameters, which would be difficult to produce by any other means. The behavior of large drops during free fall is concerned with theories of drop-size distribution in natural rain.

K. J. DeJuhasz, USA

1153. Miles, J. W., The aerodynamic force on an airfoil in a moving gust, *J. aero. Sci.* **23,** 11, 1044–1050, Nov. 1956.

The increment of lift due to a sharp-edged gust moving across a two-dimensional airfoil at a relative velocity different from the flight velocity is calculated for incompressible flow. The theoretical results are applied to the calculation of the repeated loading of a helicopter blade due to the upwash field of a wing directly beneath the blade. A. M. Kuethe, USA

1154. McNown, J. S., Hsu, E.-Y., and Yih, C.-S., Applications of the relaxation technique in fluid mechanics, *Trans. Amer. Soc. civ. Engrs.* **120,** 650–686, 1955.

Authors present a clear description and practical applications of the relaxation method. Reviewer believes report serves chiefly to advertise a powerful tool (developed elsewhere, see references cited in paper) for solving engineering problems numerically. Relaxation is essentially a method of successive approximations allowing personal judgment at each step to speed up process.

H. Z. Herzig, USA

1155. Mueller, J. N., Conversion of inviscid normal-force coef-

ficients in helium to equivalent coefficients in air for simple shapes at hypersonic speeds, *NACA TN* 3807, 31 pp., Oct. 1956.

A simple correlation factor, based on inviscid shock-expansion calculations for ideal-gas conditions, is found which permits conversion of the normal-force coefficients of simple shapes in helium to equivalent coefficients in air at Mach numbers of 12, 16, and 20. The results, although preliminary in nature, indicate that the conversion of experimental force data obtained in helium to equivalent data in air might not be overly complex and that hypersonic helium tunnels might be useful in conventional aerodynamic studies as well as in fundamental gas-dynamics studies.

From author's summary

1156. Perkins, E. W., and Jorgensen, L. H., Comparison of experimental and theoretical normal-force distributions (including Reynolds number effects) on an ogive-cylinder body at Mach number 1.98, *NACA TN* 3716, 50 pp., May 1956.

Normal-force and pressure distributions have been determined for a body of revolution consisting of a fineness-ratio-3, circular-arc, ogival nose tangent to a cylindrical afterbody 7 diameters long. The free-stream Mach number was 1.98; the angle-of-attack range was from 0° to 20°; and the Reynolds numbers, based on body diameter, were 0.15×10^6 and 0.45×10^6.

Comparisons of experimental and theoretical distributions of pressure and normal-force coefficients indicate that available theoretical methods can be expected to predict experimental results with good accuracy for angles of attack only to about 5°. The zero-lift pressure distribution is adequately predicted by Van Dyke's second-order theory.

The normal-force distributions differ significantly from those calculated in accordance with theories which include methods of estimating the effects of viscosity on the forces and moments for inclined bodies. Analysis of the data shows that these differences are, in general, attributable to inadequate estimates of the magnitude and distribution of the cross forces resulting from flow separation. Results of the tests at different Reynolds numbers show that, insofar as the viscous cross-force distribution on an inclined body is concerned, the boundary-layer flow in the axial and crossflow directions cannot always be considered independent.

From authors' summary

The following 16 papers, (Revs. 1157–1172) were published in the Proceedings of the Conference on High-speed Aeronautics, *held Jan. 20–22, 1955 at Polytechnic Institute of Brooklyn, Brooklyn, New York.*

1157. Von Karman, T., Solved and unsolved problems of high speed aerodynamics, pp. 11–39.

Paper reviews, in brief nonmathematical fashion, the present state of knowledge in high-speed external aerodynamics. Among the wide range of topics discussed are the following: Methods of linearized theory for subsonic and supersonic flow; limitations of linearized theory; higher approximations for subsonic and supersonic flow; transonic flow, including existence and uniqueness of shock-free mixed flow; hypersonic flow; boundary-layer problems, including interaction between shock wave and boundary layer in both transonic and hypersonic flow; transition and turbulent boundary layers; aerodynamic noise; aerodynamic heating; magneto-hydrodynamics and superaerodynamics. Beyond this there is little a reviewer need add, since most people working in these fields will, without any urging, want to see for themselves what the author has to say. W. G. Vincenti, USA

1158. Dryden, H. L., Transition from laminar to turbulent flow at subsonic and supersonic speeds, pp. 41–74.

This is an extremely useful summary of the current situation (primarily experimental) in the transition problem. Considerable emphasis is put on the effects of surface disturbances and heat transfer. The bibliography is reasonably complete, although the reviewer regrets the omission of H. W. Liepmann's *NACA Advance Confidential Rep.* no. 3H30 (*Wartime Rep.* no. W-107), 1943, which gave important confirmation to the measurements of Schubauer and Skramstad and added some new ideas.

S. Corrsin, USA

1159. Crocco, L., Considerations on the shock-boundary layer interaction, pp. 75–112.

The physics of the shock-wave boundary-layer interaction process is described in detail with the aid of a theoretical analysis. This analysis covers both laminar and turbulent boundary layers on insulated surfaces. The principal assumption made is that of single-parameter families of incompressible laminar and turbulent boundary layers. Use is made of the Howarth y-transformation to convert the incompressible velocity profiles to compressible flow. The analysis yields results which are in good agreement with experiment. J. Persh, USA

1160. Oswatitsch, K., and Keune, F., The flow around bodies of revolution at Mach number 1, pp. 113–131.

Computation of axisymmetric transonic flow patterns requires the solution of a mixed elliptic hyperbolic nonlinear differential equation. Authors replace the most obnoxious term of the equation by an expression which renders the equation linear and parabolic and has the proper sign in most of the flow field. After this operation the computation of the flow field is routine mathematics. The theoretical justification attempted is unconvincing, but the agreement with one wind-tunnel result is excellent.

G. Guderley, USA

1161. Busemann, A., The relation between minimizing drag and noise at supersonic speeds, pp. 133–144.

Author discusses pressure disturbance in far field around supersonic aircraft in relation to noise ("booms") caused on the ground. Most of noise reduction is due to spread of the pressure pulse with distance from aircraft; this spread is a nonlinear feature of the flow field and is estimated by methods due to the author, Friedrichs, Lighthill, and Whitham applied to simple axially-symmetric and planar shapes. Very little noise relief can be expected by reducing wave drag or increasing flight altitude; an appendix shows that effect of density variation with altitude on noise attenuation is slight.

A. E. Bryson, Jr., USA

1162. Jones, R. T., Possibilities of efficient high-speed transport airplanes, pp. 145–156.

1163. Michel, R. R., and Sirieix, M. J. J., An experimental contribution to the study of the lifting airfoil at transonic speeds, pp. 157–173.

Paper presents the results of systematic pressure-distribution tests on an NACA 64-A-010 airfoil. The tests were carried out in a 300 × 90-mm transonic tunnel at the Chalais-Meudon Fluid Mechanics Laboratory. The Reynolds number of the tests varied from about 0.41×10^6 at $M = 0.4$ to 0.83×10^6 at $M = 1.0$, and the airfoils had a laminar boundary layer with natural transition, at least up to the shock.

The paper is divided into several parts. The first part gives the results of tests at zero angle of attack and thirteen Mach numbers between 0.7 and 1.0. Next, the data are given for twenty Mach numbers between 0.61 and 1.0 at three degrees angles of attack. The over-all section lift and moment coefficient is also given at angles of 2°, 3°, and 4°, and Mach numbers from 0.41 to 1.0. Finally, the effect of angle of attack from 0 to 6° at Mach 1.0 is investigated. The Mach 1.0 tests are supplemented by

tests on an NACA 64-A-006 airfoil and serve as a confirmation of the transonic similarity laws.

H. P. Liepman, USA

1164. Schlichting, H., Some problems of cascade flow, pp. 175–187.

In this paper, author, whose previous publications dealing with a comprehensive approach to the determination of the aerodynamic characteristics of profile grids and blade rows have attracted wide attention, presents the outline of a method for solving, in the incompressible case, the "direct problem" of the theory of cascades by which the aerodynamic effect of a grid may be computed for a given blade geometry. The computation, derived from the method of singularities by introduction of judiciously chosen approximations, permits determination of the influence of variation of individual grid parameters upon both pressure distribution and losses. Its use is illustrated by examples and its validity demonstrated by comparison with corresponding exact solutions. Computed results are compared with experimental measurements.

The author states that certain recurrent functions have been tabulated; thereby the computational work has been reduced to an amount quite acceptable in engineering practice.

J. R. Weske, USA

1165. Broglio, L., Balance method in thermal stress analysis, pp. 189–211.

Paper presents some preliminary results of work dealing with thermal stresses. The problems have been solved with the help of the "balance method" (denoted briefly as B.M.), following a general and uniform technique.

The paper is divided into two parts. Part I pertains to the determination of the temperature distribution in steady flight. Part II is concerned with the determination of stresses, once the temperature distribution has been calculated. The solution is obtained through a straightforward application of the B.M. to a structure with prescribed external loads.

From author's summary by W. S. Hemp, England

1166. Duberg, J. E., High temperature structural research at the National Advisory Committee for Aeronautics, pp. 213–232.

Paper reviews experimental work on effects of elevated temperature on specific strength and specific stiffness of aircraft materials, on creep deflections of structures and creep buckling of columns, on thermal stresses and buckling caused by them, and on loss in stiffness of structures attributable to the same cause. A number of valuable theoretical-cum-empirical design formulas are stated and compared with the experiments. Work reported is of great value to designers of high-speed aircraft structures.

W. S. Hemp, England

1167. Horton, W. H., The influence of kinetic heating on the design and testing of aircraft structures, pp. 233–270.

Paper may be said to be a broad survey of the effects of aerodynamic heating on aircraft structures. The first part concerns the aerodynamic aspects of convective heat transfer from the boundary layer. After this brief introduction, author discusses various schemes of insulating and cooling a structure with remarks on their effectiveness and areas of applicability. Questions relating to heat transfer within the structure are treated with perhaps greatest emphasis on the problems introduced by mechanical joints. The phenomenon of thermal stressing is mentioned, followed by an interesting discussion of thermal fatigue and creep. Thermal buckling and creep buckling are touched on briefly. The wide field of structural design in relation to aerodynamic heating is discussed, and author points up some of the problems to be overcome; these include the problems of heat-resistant materials and adhesives as well as the problems of designing the load-carrying elements of the structure. In connection with the latter, author expresses the opinion that new and novel ideas may not be too far ahead, and then cites the example of a prestressed concrete wing recently developed by the Brequet Company of France. Finally, a survey is given of the laboratory techniques which must be developed in order to conduct experiments at high temperatures on structural components and models. The author is eminently qualified to discuss this subject, as evidenced by his excellent previous paper entitled, "Laboratory simulation of kinetic heating," *Aircr. Engng.* **26**, 303, p. 138, May 1954.

R. L. Bisplinghoff, USA

1168. Hoff, N. J., Stress distribution in the presence of steady creep, pp. 271–310.

When a machine part has to be designed for a lifetime of several years, the rates of creep that can be tolerated are exceedingly small. In a guided missile, on the other hand, much higher rates of creep, up to several per cent per hour, are admissible because of the extremely short lifetime. Author suggests that under these conditions the steady-creep deformations may be large enough to obliterate the effects of the elastic deformations and the deformations caused by primary creep. The stress distribution can then be found by applying author's elastic analogy [*Quart. appl. Math.* **12**, 1, 49–55, 1954] as follows. The creep law relates the steady-state strain rate to the stress; the corresponding elastic law relates the strain in the same manner to the stress. In both the problem of steady creep and the corresponding elastic problem, the stresses have to satisfy the same equilibrium conditions in the interior and at the surface of the considered body. Moreover, the strain rates in the problem of steady creep and the strains in the elastic problem have to satisfy compatibility conditions of identical structure. If surface tractions are prescribed over part of the surface and the displacements are prescribed to be zero over the remainder of the surface, the stress distributions for the two problems must, therefore, be identical. Unfortunately, the elastic stress-strain laws corresponding to realistic creep laws are nonlinear, and the techniques of nonlinear stress analysis are not yet sufficiently developed to make this elastic analogy very useful. An alternative plastic analogy is suggested starting from the usual creep law for uniaxial stress, which sets the strain rate equal to a power of the quotient of the stress and a reference stress. For a large value of the exponent, the relation between strain rate and stress then resembles the relation that is stipulated between strain and stress in a rigid, perfectly plastic solid, with the reference stress corresponding to the yield stress. The methods for analyzing stresses in rigid, perfectly plastic solids, which have been developed to a considerable extent during recent years, can therefore be applied to creep problems when the elastic deformations and the deformations caused by primary creep can be neglected.

The technique is illustrated by three examples concerning a redundant truss, a rigid frame, and a thick-walled tube under interior pressure. In each case an exact analysis based on the elastic analogy is compared with the much simpler approximate analysis based on the plastic analogy. It is found that the plastic analogy furnishes good approximations for the stresses but, because of the high exponent in the stress-strain rate law, poor approximations for the strain rates and, hence, the accumulated strains. Author points out that the same high exponent

has a beneficial influence in so far as the designer can provide for a considerable increase in the safety factor by a small increase in weight of the structure. Author concludes that, with this design philosophy, the plastic analogy can be useful in the approximate analysis of structures subject to creep. W. Prager, USA

1169. **Smelt, R., Test facilities for ultra-high speed aerodynamics,** pp. 311–333.

Limits of hypersonic tunnels and facilities for achieving Mach numbers above 12, like impulse tunnels, and short duration, extreme Mach number facilities are critically reviewed. Also, means of heat addition to supersonic streams and experiments to separate phenomena in hypersonic research are discussed. Hypersonic tunnels reach their engineering limitations mainly due to untenable heat-transfer rates at the nozzle throat, since supply air heating is needed to avoid air condensation for high test-section Reynolds numbers. Numerical Mach number limits of such facilities are, of course, open to argument; however, ranges are generally agreed upon. Usefulness of axisymmetric nozzles where engineering problems limiting two-dimensional nozzles are less severe may be underrated by author. Need for flight simulation of high temperatures and attending real gas effects, however, limit all standard wind tunnels certainly above Mach number 12, where large differences between tunnel and flight results must be expected.

Problems in impulse tunnels and shock tubes are discussed where real gas effects may be simulated but measuring times are very short, and, finally, the possibility of heating the supersonic stream directly by electric arcs is indicated. If such a method were successful it would certainly circumvent some limits of tunnels and shock tubes. The shortest discussion concerns the separation of individual hypersonic phenomena, which reviewer believes to be one of the most important fields until sizable impulse tunnels and successful instrumentation become available.

Several papers on the use of substitute gases and new techniques such as using a wind tunnel with a readily dissociating gas as a fluid have been written since publication of paper. Paper presents an excellent survey of test facilities for hypersonic research and development and is of great interest to workers in the field due to its critical evaluation of technical limits.

P. P. Wegener, USA

1170. **Kantrowitz, A., A survey of physical phenomena occurring in flight at extreme speeds,** pp. 335–339.

Concentration of various components of air is shown for temperatures up to 9000 K, based on calculations employing standard statistical mechanics, for a density of 10^{-3} atmospheres. Specific heat of air at a density of 1/10 atmosphere, as a function of temperature for the same temperature range, shows that, in the higher flight speeds, heat capacity due to dissociation is overwhelmingly larger than other heat capacities. Electrical conductivity of air as measured in a shock tube is shown to be so great that appreciable magneto-hydrodynamic forces can be exerted on air under extreme flight conditions.

I. Michelson, USA

1171. **Ferri, A., Recent theoretical work in supersonic aerodynamics at the Polytechnic Institute of Brooklyn,** pp. 341–362.

Results of theoretical work on two problems are summarized. The first problem concerns the properties of the flow field about practical aerodynamic configurations (without recourse to linearization of the equations of motion). The method is to superimpose small disturbances on a basic nonlinearized flow field. Mixed-type (hyperbolic and elliptic) flows are considered. Author shows that under certain conditions transition from hyperbolic to elliptic flow requires two sonic lines. The second problem relates to interference problems with special emphasis on the high Mach number range. In the case of wing-body combinations, the flow field due to the body is simulated by a source distribution in a reference plane and interference effects are determined by linear methods. Integral theorems, defining interference effects on lift and drag, are derived. These appear to be very useful for evaluating configurations designed for high Mach number flight. Viscous effects are neglected. H. Mirels, USA

1172. **Libby, P. A., and Bloom, M. H., Facilities for experimental high speed aerodynamics research at the Polytechnic Institute of Brooklyn,** pp. 363–373.

Tunnel supply air is provided by a central storage system of 2700 cu ft and a maximum pressure of 2800 psi. From this storage system, a number of supersonic blowdown tunnels and a hypersonic facility are operated. Supersonic tunnels are flexible to permit operation of various sizes of test sections, ranging from about 10 in. to 18 in. in size, which can be changed readily, using the same settling chambers. High-pressure storage permits economical operation at full-scale Reynolds numbers at low Mach numbers. Pressure and temperature are held constant in supply sections. In line with trying to simulate Reynolds numbers at low Mach numbers, it is attempted to simulate free-flight temperatures in addition to Mach number in the hypersonic regime. An intermittent convection heater filled with electrically preheated aluminum-oxide spheres puts out up to 3000 R, and a second-stage compression heater, using the pebble heater as preheater, may work up to 8000 R at high pressure. Free-flight temperatures up to Mach numbers below 10 may thus be simulated, while extreme Mach numbers such as 15 may be operated free of air condensation without temperature simulation. Intermittent blowing periods are long enough to utilize conventional instrumentation.

Research is directed towards those hypersonic problems where real gas properties become of importance, cooling systems are needed, etc. Facilities and program are beautifully integrated, and many design details are solved with great ingenuity on a relatively low cost basis in Professor Ferri's efforts to achieve real gas test environments. P. P. Wegener, USA

Compressible Flow, Gas Dynamics

(See Revs. 1171, 1186, 1187, 1188, 1189, 1190, 1192, 1194, 1195, 1197, 1198, 1208, 1259)

Wave Motion in Fluids

(See Rev. 1262)

Turbulence, Boundary Layer, etc.

(See also Revs. 1147, 1173, 1213, 1251)

Book—1173. Boundary layer effects in aerodynamics (Proc. Nat. Phys. Lab. Symposium, 1955), London, Her Majesty's Stationery Office, 1955, iv + 405 pp. 1£ 10s.

This volume contains nine papers presented at the Symposium of problems of boundary-layer flow held at the National Physical Laboratory, Teddington, in 1955, on the completion of the first

half century of this outstanding theory of fluid dynamics. Papers cover a very wide field, from fundamental research to practical application, and from low speed to supersonic flow, laminar and turbulent flow including transition. The opening address by L. Howarth gives a survey of the more theoretical subjects, two-dimensional, three-dimensional, and compressible boundary layers; it is restricted to British papers only.

A paper by R. Timman concerns approximate methods for three-dimensional laminar boundary layers, while M. B. Glauert and M. J. Lighthill deal with the axisymmetric boundary layer on a long thin cylinder. In a very remarkable paper, M. Gregory, J. T. Stuart, and W. S. Walker present experimental and theoretical results on the transition in the flow on a rotating disk. G. B. Schubauer and P. S. Klebanoff contribute new experimental results on the intermittent nature of transition (turbulent spots). Two papers by L. W. Holder, G. E. Gadd and by H. H. Parcey are concerned with shock-induced separation of boundary layers in supersonic and transonic flow, respectively. The remaining three papers are closer to aeronautical engineering: D. Küchemann, "The effect of viscosity on the type of flow on swept wings"; R. C. Pankhurst, "Recent British work on boundary-layer control"; A. D. Young, S. Kirkby, "The profile drag of biconvex and double-wedge wing sections at supersonic speeds."

H. Schlichting, Germany

1174. Steketee, J. A., Some problems in boundary-layer transition, *Inst. Aerophys. Univ. Toronto UTIA Rep.* no. 38, 95 pp. + 8 figs. + 1 table, Apr. 1956.

A qualitative review is given of the current ideas on transition from laminar to turbulent flow in a boundary layer. Particular attention is given to the growth of turbulent spots, and an alternate derivation is given of one of the rate-of-growth formulas in an early paper by reviewer. After rederiving the turbulence equations and the boundary layer via the Oseen equations, a series of problems of flow disturbances are discussed. These purport to describe the growth of the turbulence behind a disturbance in a boundary layer. The choice of disturbance is dictated by mathematical convenience and has interest as secondary flows behind the mathematically described, physically none-too-realistic, disturbances. The solution include those with vorticity aligned with the free streamlines which are clearly important as initiators of turbulent spots in many cases. The various cases solved are neither initiated by, nor interpreted in detail, in physical significance. The connection of these solutions to the locus of growth of turbulent spots in a boundary layer is obscure.

H. W. Emmons, USA

1175. von Doenhoff, A. E., and Horton, E. A., A low-speed experimental investigation of the effect of a sandpaper type of roughness on boundary-layer transition, *NACA TN* 3858, 43 pp., Oct. 1956.

An investigation was made in the Langley low-turbulence pressure tunnel to determine the effect of size and location of a sandpaper type of roughness on the Reynolds number for transition. Transition was observed by means of a hot-wire anemometer located at various chordwise stations for each position of the roughness. These observations indicated that when the roughness is sufficiently submerged in the boundary layer to provide a substantially linear variation of boundary-layer velocity with distance from the surface up to the top of the roughness, turbulent "spots" begin to appear immediately behind the roughness when the Reynolds number based on the velocity at the top of the roughness and the roughness height exceeds a value of approximately 320.

At Reynolds numbers even slightly below the critical value (value for transition), the sandpaper type of roughness introduced no measurable disturbances into the laminar layer downstream of the roughness. The extent of the roughened area does not appear to have an important effect on the critical value of the roughness Reynolds number.

From authors' summary

1176. Hansen, A. G., and Herzig, H. Z., On possible similarity solutions for three-dimensional incompressible laminar boundary layers I—similarity with respect to stationary rectangular coordinates, *NACA TN* 3768, 30 pp., Oct. 1956.

This theoretical study presents solutions of mainstream flow patterns for all possible incompressible laminar boundary-layer flows which have classical similarity with respect to rectangular coordinate systems. These solutions are obtained and presented for nine cases. For example, the cases of accelerating or decelerating the mainstream flows for general streamline paths are presented. The solutions are tabulated to include the mainstream velocity components, the generalized similarity parameter, and the final set of ordinary differential equations for each family of mainstream flows. It is to be noted that the final solutions for the boundary-layer velocity components have not been carried out and that the actual numerical solutions for the ordinary differential equations derived have been considered beyond the scope of the investigation.

Reviewer recommends this analysis for those engaged in turbine or turbomachine design.

G. B. White, USA

1177. Holzhauser, C. A., and Hall, L. P., Exploratory investigation of the use of area suction to eliminate air-flow separation in diffusers having large expansion angles, *NACA TN* 3793, 18 pp., Oct. 1956.

An exploratory investigation has been made with area suction used for boundary-layer control in conical diffusers with expansion angles of 30° and 50° and with an area ratio of 2. These tests, made at a mean inlet Mach number of about 0.2, indicated that the air-flow separation was eliminated by the use of area suction, and the resulting total-pressure and static-pressure losses were less than those for a 10° diffuser without boundary-layer control. The air-flow separation was eliminated in the 30° and 50° diffusers with suction mass flows of 3 and 4 of the inlet mass flows, respectively.

From authors' summary

1178. Di Prima, R. C., and Dunn, D. W., The effect of heating and cooling on the stability of the boundary-layer flow of a liquid over a curved surface, *J. aero. Sci.* **23,** 10, 913–916, Oct. 1956.

Paper is a mathematical contribution to the present depressing state of boundary-layer theory. The authors consider approximate linearized disturbance equations, and work to the following conclusion " . . . that heating and cooling have only a slight influence on the three-dimensional instability of boundary layers over curved surfaces for a liquid, (is) likely also true for gas at low Mach numbers and rates of heat transfer, when density variations are negligible. . . . (It) may not be true. . . in other circumstances."

As a small essay in applied mathematics the paper appears to be estimable.

R. Stevenson, USA

1179. Reid, W. H., On the approach to the final period of decay in isotropic turbulence according to Heisenberg's transfer theory, *Proc. nat. Acad. Sci. Wash.* **42,** 8, 559–563, Aug. 1956.

Author assumes that Heisenberg's expression for the energy transfer distribution is valid in the final period of decay, even though energy transfer is small under such conditions, and uses it to determine the transfer distribution by substituting the usual expression for the energy spectrum $E(k)$ in the final period. The transfer distribution so obtained is regarded as valid asymptotically, and may be made the starting point for an asymptotic expansion of the spectrum and transfer distribution in time.

The assumption that one of the customary expressions for the transfer distribution in terms of E and k alone applies in the final period of decay is not immediately plausible, since the usual arguments in their favor imply predominance of inertia forces. The direct consequences of this assumption should therefore be

kept clearly in mind; one of them is the author's finding that the skewness factor of the velocity gradient is non-zero in the final period (and that consequently the complete probability distribution of velocity is not asymptotically normal).

G. K. Batchelor, England

Aerodynamics of Flight; Wind Forces

(See also Revs. 990, 998, 999, 1087, 1153, 1156, 1157, 1171, 1172, 1199, 1200, 1204, 1208, 1209, 1210, 1211, 1214, 1305)

Book—**1180. Alexandrow, W. L., Airplane propellers [Luftschrauben]**, Berlin, VEB Verlag Technik, 1954, 445 pp.

The chapter on the history of the propeller contains some remarkable statements: "The great Russian inventor A. F. Moshaiski was the first engineer of the world to build an airplane which lifted itself into the air"; "Joukowsky's school by far outranked the research of foreign scientists in the propeller field"; "The Russian school has kept its leading role until today." Nobody will deny the outstanding contributions of Joukowsky (spelled Shukowski in this German translation of the Russian edition of 1951) and his school, and other Russian scientists. However, it is surprising that names like Lanchester, Prandtl, Karman are not mentioned at all. The reader must gain the impression that the Clark Y and RAF-6 airfoils are Russian inventions. The list of authors contains 30 names, all Russian. Further surprises: A curve sheet of lift coefficient c_a versus angle of attack for various thickness ratios $\bar{c}$ shows c_a maximum = 0.6 only at $\bar{c}$ = 6.9% and a constant increase of c_a maximum up to $\bar{c}$ = 21%, with no reversal of trend beyond $\bar{c}$ = 13%. Corrections of airfoil coefficients at high Mach numbers refer only to lift and drag, not to moment coefficients.

A few minor points of similar character, however, do not diminish the over-all value of the book, which is a high-level, first-rate text for engineers, scientists, and students, unusually comprehensive, and easily understandable. The theoretical part treats momentum theory without and with rotation, blade element theory, their combination, vortex theory, hub design, stress analysis, unbalance, vibration, yawing, dynamics of the governor, unsteady motion, and the combination of the propeller with the airplane and the reciprocating engine or turbine. Much space is devoted to production techniques, choice of type, determination of faulty operation, stability and control, noise, testing methods. The chapters are well balanced in length and appropriately illustrated (332 drawings and pictures). The book clearly shows that the author is not just a writer but a scientist and an experienced practical engineer. The presentation uses simple mechanical analogies and throughout stresses the physical basis, the simplifying assumptions necessary for the mathematical development, the applicability of the results as influenced by these simplifications, and the interaction of theory and practice; thus the reader never loses sight of the overall problem.

Although all the individual topics have been treated somewhere in the English propeller literature, reviewer does not know of any book which combines them so comprehensively, including dynamics and vibration. The proofreading has been very thorough. Not treated is the supersonic propeller which was already declassified in the U.S.A. at the time of publication of the book. Translation into English would be desirable. G. Graetzer, USA

1181. Oroveanu, T., Contribution to the estimation of the circulation distribution around an airfoil influenced by the propeller jet (in German), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1**, 1, 59-70, 1956.

Problem stated in the title is treated under the following assumptions: (1) The velocities are such that the air can be considered as incompressible; (2) the air jet behind the propeller had the form of circular cylinder; (3) the axial velocity of air particles is constant over the cross section of this cylinder—only the influence of axial velocity is taken into account; (4) the airfoil intersects the axis of the propeller jet.

As the motion is irrotational in the whole space outside the airfoil and the vortex layer, the velocity potential is introduced and the problem is reduced to a boundary-value problem. For the sake of simplicity, the special case in which the airfoil is of smallest induced resistance is considered. Thus the circulation distribution is determined by means of the complex potential which is given by a power series, and it is shown how the coefficients of the series can be determined.

An example illustrating the applications of the general method is calculated. J. Beranek, Czechoslovakia

1182. Weinig, F. S., A generalized method of computing the influence of spacing and stagger on the velocity distribution of a profile in a cascade, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955. 343-353.

A close relation to the conformal mapping of the profile to the velocity distribution has been established. A series method is given for computing the velocity distribution in a cascade of moderate solidity, taking into account spacing and stagger. Reviewer feels that the method is useful, as higher approximations can be got easily. It would have been more interesting if experimental verification had been carried out.

Y. V. G. Acharya, India

1183. Mazelsky, B., Theoretical aerodynamic properties of vanishing aspect ratio harmonically oscillating rigid airfoils in a compressible medium, *J. aero. Sci.* **23**, 7, 639-652, July 1956.

On the basis of Munk's airship theory (the flow is presumed essentially two-dimensional in planes perpendicular to the free-stream direction), Jones had determined the aerodynamic properties of low-aspect-ratio airfoils for the steady planar case, the results of which Garrick extended to the transient incompressible case. This paper presents an extension of Garrick's results, including the effects of compressibility. The basic differential equation is the linearized two-dimensional wave equation for the velocity potential, and author gives solutions (partly in closed form) for the required boundary conditions in terms of Mathieu functions. These functions are tabulated for the complete range of reduced frequencies. The significant variable introduced in defining the oscillatory coefficients is the single parameter k_0M (k_0 reduced frequency in local half spans; M Mach number). Numerical coefficients are computed for use in evaluating the expressions for lift, pitching, and rolling moment for rectangular and delta planforms. Comparisons of the oscillatory coefficients based on compressible and incompressible flow indicate that, for the range of reduced frequencies applicable for flutter, the effects of compressibility can be considered negligible. The solutions agree with the analytical expressions obtained by Merbt and Landahl for the delta wing (for the incompressible case the agreement is exact).

M. Schafer, Germany

1184. Oswald, T. W., Dynamic behavior during accelerated flight with particular application to missile launching, *J. aero. Sci.* **23**, 8, 781-791, Aug. 1956.

Linearized theory for stability of an accelerating missile is extended to case of vehicle with appreciable aerodynamic lift and damping (appreciable wing and control surface area). Results show that effects of acceleration, oscillation frequency, launch angle, thrust misalignment and wind can be readily evaluated when the relative damping has been determined. Graphs are presented of functions needed to carry out solutions. Paper is primarily mathematical, but results can be applied without extensive mathematical background. No comparison with experimental results is presented.

E. W. Price, USA

1185. Jasinski, J., Helicopters, their operation and structure (in Polish), *Tech. Lotnicza* **10**, 3, 82-88, May-June 1955.

Author describes flow phenomena during action of helicopter rotor, illustrated with many diagrams and sketches, based mostly upon Russian sources. M. Z. Krzywoblocki, USA

1186. Duncton, P. J., Supersonic flight—aerodynamics—aircraft and missiles, *J. roy. aero. Soc.* **60**, 551, 697–705, Nov. 1956.

1187. Cleaver, A. V., Supersonic flight—propulsion, *J. roy. aero. Soc.* **60**, 551, 705–711, Nov. 1956.

1188. Farrar, D. J., Supersonic flight—structures, *J. roy. aero. Soc.* **60**, 551, 712–720, Nov. 1956.

1189. Gardner, H. H., Supersonic flight—control and allied problems, *J. roy. aero. Soc.* **60**, 551, 720–731, Nov. 1956.

1190. Dunsby, J. A., Supersonic flight—summary of the discussions, *J. roy. aero. Soc.* **60**, 551, 732–735, Nov. 1956.

1191. Martina, A. P., The interference effects of a body on the spanwise load distributions of two 45° sweptback wings of aspect ratio 8.02 from low-speed tests, *NACA TN* 3730, 47 pp., Aug. 1956.

Tests of two wing-body combinations have been conducted in the Langley 19-ft pressure tunnel at a Reynolds number of 4×10^6 and a Mach number of 0.19 to determine the effects of the bodies on the wing span load distributions. The wings had 45° sweepback of the quarterchord line, aspect ratio 8.02, taper ratio 0.45, and incorporated 12-percent-thick airfoil sections streamwise. One wing was untwisted and uncambered whereas the second wing incorporated both twist and camber. Identical bodies of revolution, of 10:1 fineness ratio, having diameter-to-span ratios of 0.10, were mounted in mid-high-wing arrangements. The effects of wing incidence, wing fences, and flap deflection were determined for the plane uncambered wing.

The addition of the body to the plane wing increased the exposed wing loading at a given lift coefficient as much as 10% with the body at 0° incidence and 4% at 4° incidence. The body-induced lift disappeared near maximum lift in both cases. The bending-moment coefficients at the wing-body juncture were increased about 2% with the body at 0° incidence, whereas the increases were as much as 10% with the body at 4° incidence.

The spanwise load distributions due to the body on the plane wing as calculated by using a swept-wing method employing 19 spanwise lifting elements and control points generally showed satisfactory agreement with experiment. The spanwise load distributions due to body on the flapped plane wing and on the twisted and cambered wing were dissimilar to those obtained on the plane wing. Neither of the methods of calculation which were employed yielded distributions that agreed consistently with experiment for either the flapped plane wing or the twisted and cambered wing.

From author's summary

1192. Emerson, H. F., Wind-tunnel investigation of the effect of clipping the tips of triangular wings of different thickness, camber, and aspect ratio—transonic bump method, *NACA TN* 3671, 183 pp., June 1956.

The investigation reported herein was conducted on a transonic bump to determine the aerodynamic characteristics of a series of triangular wings. Four basic triangular-wing planforms having aspect ratios of 2.0, 2.5, 3.0, and 4.0 were tested. The tips of these wings were progressively clipped to provide taper ratios of 0.1, 0.2, 0.3, 0.4, and, in some cases, 0.5. The NACA 63A00X profile was used with thickness-to-chord ratios of 0.02, 0.04, and 0.06. Wings having the NACA 63A(1.5)04 section were also investigated for each aspect ratio. Data were obtained over a Mach number range from 0.60 to 1.10 corresponding to a test Reynolds number range from 1.85 million to 2.90 million. Lift, drag, and pitching-moment coefficients are presented for each of the wings investigated.

In general, the greatest decrease in drag-rise factor appeared with the change in taper ratio from 0 to 0.1.

From author's summary

1193. Sorensen, N. E., and Hopkins, E. J., Comparison between experimental and predicted downwash at a Mach number of 0.25 behind a wing-body combination having a triangular wing of aspect ratio 2.0, *NACA TN* 3720, 29 pp., May 1956.

A study was undertaken to evaluate a method for predicting the downwash in a transverse plane behind a wing-body combination throughout an angle-of-attack range from 0° to 20°. The predicted downwash was calculated by a numerical method in which an array of discrete vortexes was allowed to roll up. The wing vortexes were assumed to emanate from the trailing edge of the wing with their positions and strengths determined from the measured spanwise distribution of load.

The wing-body combination had a ratio of maximum body diameter to wing span of 0.259, a triangular wing with an aspect ratio of 2.0, and a body of revolution with a fineness ratio of 12.5. Comparisons are made between the experimental and predicted values for the downwash and for the spanwise distribution of load at a Mach number of 0.25. The positions of the vortex cores indicated by the tuft-grid technique, the water-tank technique, and the numerical method are also compared.

The downwash predicted by the numerical method showed general agreement with the experimental downwash at angles of attack up to about 6° to 8°. Above these angles considerable disagreement existed between the predicted and experimental downwash. These differences are attributed in part to flow-separation effects, since flow studies have indicated that the vortex sheet emanates ahead of the wing trailing edge rather than at the wing trailing edge, as assumed in the numerical method.

From authors' summary

1194. Perkins, E. W., and Kuehn, D. M., Comparison of the experimental and theoretical distributions of lift on a slender inclined body of revolution at M = 2, *NACA TN* 3715, 39 pp., May 1956.

Pressure distributions and force characteristics have been determined for a body of revolution consisting of a fineness ratio 5.75, circular-arc, ogival nose tangent to a cylindrical afterbody for an angle-of-attack range of 0° to 35.5°. The free-stream Mach number was 1.98 and the free-stream Reynolds number was approximately 0.5×10^6, based on body diameter.

Comparison of theoretical and experimental pressure distributions shows that, for zero lift, either slender-body theory or higher order theories yield results which are in good agreement with experiment. For the lifting case, good agreement with theory is found only for low angles of attack and for the region in which the body cross-sectional area is increasing in the downstream direction. Because of the effects of cross-flow separation and the effects of compressibility due to the high cross-flow Mach numbers at large angles of attack, the experimental pressure distributions differ from those predicted by potential theory.

Although flow about the inclined body was, in general, similar to that assumed as the basis for Allen's method of estimating the forces resulting from viscous effects [*NACA RM* A9I26], distribution of the forces was significantly different from that assumed. Nevertheless, lift and pitching-moment characteristics were in fair agreement with estimated values.

From authors' summary

1195. Donov, A. E., A flat wing with sharp edges in a supersonic stream, *NACA TM* 1394, 48 pp., Mar. 1956. (Translation from *Izv. Akad. Nauk SSSR*, pp. 603–626, 1939.)

A basic treatment is given for the approximate solution of the problem of two-dimensional supersonic flow past a thin wing at small angles of attack. The pressure distribution at the surface, the lifting force, and the wave drag are determined.

From author's summary

1196. Sutter, J., Reverse thrust for jet transports, *SAE Trans.* **63**, 379–385, 1955.

A study of various stopping methods indicates that reverse thrust would have to be developed for jet engines if jet transports are to

ave satisfactory operational flexibility. Requirements for reverse hrust are, therefore, discussed in this paper.

Primary reverser-design objectives are inherent safety and re-iability, stopping comparable to present-day equipment, lack of ffect on engine operation, and need for ground-run control only. uthor shows that a jet transport using reverse thrust has a stop-ing distance on smooth ice consistent with a dry-runway brakes-lone stop.

The effects of reverser malfunctions on airplane flying char-cteristics are compared to the effects of reversible-propeller alfunctions. From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 1183)

1197. Nelson, H. C., and Cunningham, H. J., Theoretical vestigation of flutter of two-dimensional flat panels with one rface exposed to supersonic potential flow, *NACA TN* 3465,) pp., July 1955.

Mechanical displacement behavior of panel is described by miliar differential expression including mass, bending, and embrane effects, and uniform properties. Effects of still, infinite acoustic" air space on one side and supersonic nonstationary ow on the other side of panel is described by conventional linear tegral operators. Resulting homogeneous integro-differential uation for "system" is solved by virtual displacement process r several boundary conditions and a range of relevant parameters. olution process is slightly unconventional in cases of non-zero embrane effects, where virtual displacements to satisfy complete uation *with* membrane effects are formulated from the eigen-nctions of equation "shortened" by membrane term. Regardless success of "numerical" results this might raise objections sed on uniqueness considerations. Condition for nontrivial rtual displacements is used to define real parameter manifolds r vanishing "residual" damping, using familiar complex stiffness ncept. This manifold complex becomes more complicated and ifts location with the degree of approximation. It appears fficult, based on a procedure of this type, to make systematic atements about relative disposition of these manifold complexes. Precision of delineation of stability boundaries is involved. ny interesting and rational appearing results are obtained. For ro membrane effects these provide useful comparisons with other rk. Parameters varied include relative densities, stiffnesses, eeds, membrane tensions, damping. Numerous convenient agrams are given for estimating thickness ratio to avoid in-ability. Authors claim that work suggests sufficiently thick nels are free of instability for any given supersonic speed. An interesting question appears to arise regarding the dis-ppearance, for some parameter combinations, of stability mani-ld intersections defining the free panel vibration in a vacuum. he appearance of exact solutions and systematic test results ill mark a valuable stage in this field.

P. R. Hardesty, USA

1198. Drake, D. G., The motion of an oscillating aerofoil in a mpressible free jet, *J. roy. aero. Soc.* **60,** 549, 621–623, Sept. 56.

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 1040, 1164, 1230, 1231, 1232, 1236, 1281)

1199. Lieblein, S., and Roudebush, W. H., Low-speed wake aracteristics of two-dimensional cascade and isolated airfoil ctions, *NACA TN* 3771, 49 pp., Oct. 1956.

The wake and its decay behind a cascade of profiles are im-rtant for conduct and evaluation of cascade tests and for the interference between rotating and stationary blade rows. Available test data on single as well as cascade profiles have been analyzed under simplifications such as constant direction and static pressure across the cascade spacing and of constant velocity outside of the wake. The significant quantities such as minimum velocity, form factor, momentum thickness, full or geometric thickness dependent on distance from the profile trailing edge, are approximated by directly applicable equations. Total pressure loss, total pressure defect, and air outlet angle are related to these quantities.

For performance tests of cascades, observations 1/2 or at least 1/4 chord length downstream of the trailing edge are to be recommended.

Author feels that additional data should be obtained to more conclusively define the development of the cascade wake. Reviewer's opinion is that because of the deflection effected by the cascade the variation of direction and magnitude of velocity across the cascade spacing outside of the wake should be observed and taken into account in future work, especially if applicability to large turning angles as in turbines is to be included.

F. Weinig, USA

1200. Schulz, G., Forces exerted on a jet engine and its cowling (in German), *Z. Flugwiss.* **4,** 9, 285–290, Sept. 1956.

The forces on the nacelle of a jet engine are described. Lift and induced drag forces are included in the analysis. A method of computing the shift in the neutral point (for static stability) is given. While the analysis is for incompressible (external) flow, reviewer believes that the problems discussed are somewhat greater for supersonic flight. W. Daskin, USA

1201. Wolf, J., Extraction of compressed air and determination of characteristic properties of compressor and turbine of turbojet engine (in Polish), *Tech. Lotnicza* **10,** 2, 34–44, Mar.-Apr. 1955.

Article describes thermodynamic characteristic properties of compressor and turbine of turbojet engine and is illustrated with many diagrams. M. Z. Kzywoblocki, USA

1202. Dunavant, J. C., and Erwin, J. R., Investigation of a related series of turbine-blade profiles in cascade, *NACA TN* 3802, 100 pp., Oct. 1956.

An application of airfoil design methods was used to design series of related turbine-blade profiles to satisfy the conditions of inlet flow angle and turning angle encountered in the usual range of turbine operation. A series of blade profiles applicable to most turbine blading requirements and a secondary series with particular reference to impulse conditions were designed. Five blade sections from these series ranging in mean-line turning angles from 65° to 120° were tested in low-speed cascade tunnels. From low-speed test results, optimum blade angles of attack were selected at each test condition. The induced angle and the deviation angle of the flow were determined from the low-speed data. If these angles are known for the solidity and inlet angle of an application, the necessary camber is specified. A method of predicting high-speed pressure distributions from low-speed cascade-test results is presented to extend the usefulness of the low-speed data. Sample high-speed tests of two of the five blade sections were made at Mach numbers up to the critical value. The results indicated satisfactory flow conditions in all the blade passages tested. From authors' summary

1203. Whitney, W. J., Tabulation of mass-flow parameters for use in design of turbomachine blade rows for ratios of specific heats of 1.3 and 1.4, *NACA TN* 3831, 111 pp., Oct. 1956.

Mass-flow tables for ratios of specific heats γ of 1.3 and 1.4 are presented for the entire range of critical velocity ratio. The tables enable a quick and accurate determination of the integrated average specific mass flow across a region where the end-point velocities are known, commensurate with the assumptions that the total state is constant and the static pressure varies linearly between the two velocities. A numerical example is included to

illustrate the use of the tables. All quantities are in nondimensional form and are tabulated against critical velocity ratio. The tables include specific-mass-flow parameter and ratio of static to total pressure. From author's summary

1204. Corson, T. M., The propeller-turbine in airline service, *J. roy. aero. Soc.* **60,** 549, 590–604, Sept. 1956.

Paper gives an account of the engineering and operational aspects of the introduction and first three years' operation by British European Airways of the first propeller-turbine engine to go into airline service—the Rolls-Royce Dart which powers the Vickers Viscount airliner. The origin of this type of gas-turbine engine and its chief advantages and disadvantages are considered. The main features and operational characteristics of the Dart engine are detailed. The training, operational handling, flight planning and maintenance aspects of the introduction and operation of the Dart engine in the Viscount are reviewed, and the experience accumulated is summarized.

It is noted that, apart from all the new ground that has had to be covered and all the associated development, no special problems have been encountered. Considerable advantages in respect of engineering and operational simplification have been demonstrated. Experience indicates that this type of engine has good reliability and long overhaul life characteristics, and confirms its general suitability for medium-speed air transportation. Paper ends with mention of some of the probable trends of propeller-turbine development, and with suggestions for some additional improvements, which the author considers would benefit civil operators. From author's summary

Flow and Flight Test Techniques

(See also Revs. 979, 988, 1192, 1226)

1205. Numachi, F., Murai, H., and Abe, S., Streamlined pitot-tube bar for measuring water flow in large pipe, *Trans. ASME* **78,** 5, 1079–1089, July 1956.

Theoretical and experimental studies were conducted to determine the best cross-sectional form for a pitot-tube bar capable of measuring both static and total pressures. The new design permits measurement of static pressure at each location at which the total pressure is determined; this represents an advance over measuring static pressure at the wall only. The necessity for adequate ruggedness to permit use in large water conduits was also considered. Coordinates of the "best" shape and calibrations of models of that shape with respect to velocity and angle of attack are presented.

A large-scale pitot-tube bar (60-mm chord, 2 m long, 10 measuring stations) was used to measure velocities in a 2-m duct carrying water from a pumping station. No absolute calibration of so large a device was possible, hence authors must assume that effects of such things as turbulence and radial flow are negligible C. L. Coldren, USA

1206. Jorissen, A. L., A new development in flow measurement: The dall flow tube, *Proc. Amer. Soc. civ. Engrs.* **82,** HY4, (*J. Hydr. Div.*) Pap. 1039, 13 pp., Aug. 1956.

The Dall flow tube, as now constructed, offers the two-fold advantage of a great compactness and a low head loss. It is only slightly more sensitive to the conditions of installation than standard venturi tubes.

For Dall flow tubes with throat-to-inlet diameter ratios β not more than 0.75 (usual limit for venturi tubes), the coefficient of discharge can be predicted within 1%. For larger values of β, direct calibration under upstream installation conditions is recommended, unless larger tolerances on coefficient value are acceptable. From author's summary

1207. Cross, S. H., and Steckelmacher, W., Leak detection by vacuum techniques, *Research, Lond.* **9,** 4, 124–131, Apr. 1956.

Vacuum techniques are being increasingly applied to leak detection—for example, in testing mercury arc rectifiers, hermetically sealed meters for the aircraft industry, etc. The methods are based either on comparative measurement of the degree of vacuum or on direct location of the site of a leak by the use of a specific test gas. Authors describe current practice in this field and conclude with a brief section defining the units of leakage rate. From authors' summary

1208. Bryant, L. W., and Garner, H. C., Control testing in wind tunnels, *Aero. Res. Counc. Lond. Rep. Mem.* 2881, 56 pp., 1956.

The effects of model scale and tunnel-wall interference are summarized in a thorough discussion of a systematic procedure for the correction of subsonic wind-tunnel data to free-flight conditions. Consideration includes the inducement and control of transition, partial span aerodynamic controls, swept planforms, and Reynolds number, as well as significant model construction details. Numerical examples illustrate the magnitudes implicit in the suggested formulas. Scale effects are shown to be of primary importance for control surface aerodynamic derivatives. J. R. Baron, USA

1209. Jaquet, B. M., and Fletcher, H. S., Experimental steady-state yawing derivatives of a 60° delta-wing model as affected by changes in vertical position of the wing and in ratio of fuselage diameter to wing span, *NACA TN* 3843, 20 pp., Oct. 1956.

An investigation was made in the Langley stability tunnel to determine the effects on the steady-state yawing derivatives of the vertical position of the wing for a 60° delta-wing model having ratios of fuselage diameter to wing span of 0.123, 0.165, and 0.246. The test Mach number was 0.13 and the Reynolds number was 1.65×10^6. From authors' summary

1210. Beeler, D. E., Bellman, D. R., and Saltzman, E. J., Flight techniques for determining airplane drag at high Mach numbers, *NACA TN* 3821, 40 pp., Aug. 1956.

The measurement of total airplane drag in flight is necessary to assess the applicability of wind-tunnel model data. The NACA High-Speed Flight Station has investigated and developed techniques for measuring the drag of high-speed research airplanes and current fighter-type airplanes. The accelerometer method for determining drag was found to be the most satisfactory method for research works, because it is the only method permitting a complete coverage of the Mach number and angle-of-attack capabilities of an airplane.

Determining drag by the accelerometer method requires the accurate measurement of longitudinal and normal accelerations, angle of attack, and engine thrust. In addition, the static pressure, airspeed, airplane weight, and longitudinal control positions must be measured. The accurate measurement of longitudinal and normal acceleration can be made and recorded by means of specially constructed mechanical accelerometers that have been developed by the NACA. Fuselage nose booms are used to reduce the flow-field errors in the measurement of static pressure, airspeed, and angle of attack. The errors can be reduced further to an acceptable level by established calibration techniques. Satisfactory methods are available for determining in flight the thrust of turbojet-afterburner and rocket engines.

The flight drag data generally can be separated into components consisting of trim, skin-friction, pressure-induced, and wave drags. The comparison of flight and wind-tunnel data must be made on the basis of component drags if a proper interpretation of the results is to be obtained. From authors' summary

1211. Cooney, T. V., and Schott, R. L., Initial results of a flight investigation of the wing and tail loads on an airplane

uipped with a vane-controlled gust-alleviation system, *NACA* N 3746, 31 pp., Sept. 1956.

A flight investigation has been made of wing and horizontal-il loads and spar strains on a twin-engine light transport air-ane which was modified for the installation of a control sys-m that would alleviate airplane motions in turbulent air and us improve passenger comfort. In the control system used, anges in the angle of attack produced by gusts were sensed a vane which causes the trailing-edge flaps and ailerons to flect in order to counteract lift. The elevator was split and d the outer parts were geared to the flaps to balance pitch-g moment.

The results presented are from an initial analysis of sample the measurements obtained in flight through clear-air turbu-nce with the control system on and off and represent the ini-l evaluation of the gust-alleviation-system effectiveness, t necessarily the optimum that can be obtained. There were dications that a reduction of 43% in root-mean-square normal celeration at the airplane center of gravity was accomplished. his reduction in normal acceleration was accompanied by a duction in main-spar bending strains of the wing; however, ear strains in both the main and rear spars of the test-airplane ing were increased because of operation of the trailing-edge aps in the alleviated airplane configuration. Horizontal-tail ear and bending strains were increased because of operation the split elevator on the gust-alleviated airplane. Increases the magnitude and frequency of occurence of some of the rains in the wing and tail structure in rough air which are ssociated with operation of the alleviation controls indicate at fatigue would be an important consideration in designs ilizing this type of gust-alleviation system. Measurements wing and horizontal-tail aerodynamic loads obtained in a ull-up maneuver in smooth air with the system on and off are so presented. From authors' summary

1212. Brown, C. E., and Heinke, H. S., Jr., Preliminary wind-nnel tests of triangular and rectangular wings in steady roll Mach numbers of 1.62 and 1.92, *NACA TN* 3740, 36 pp., June 956.

The damping-in-roll coefficients for a series of thin triangular anform wings and two rectangular wings have been obtained in e Langley 9-in. supersonic tunnel. The triangular-wing series nsisted of nine wings of vertex angles such that a range of ading-edge positions ahead of and behind the Mach cone was tained at two Mach numbers, 1.62 and 1.92. The rectangular ngs were of aspect ratio 2.00 and 2.73. All the wings were sted in the presence of a body of revolution.

It was found that the damping in roll of the rectangular wings s very close to that predicted by linear theory for isolated ngs.

The triangular wings gave results approximately 10% below at predicted when the wing leading edges were well ahead of behind the Mach cone. Somewhat greater reductions in the mping coefficients from the linear theory were found when e leading edges were in the vicinity of the Mach cone.

From authors' summary

1213. Allen, L. D., and Burrows, F. M., Flight experiments the boundary layer characteristics of a swept back wing, ll. Aero. *Cranfield Rep.* 104, 30 pp. + 28 figs., July 1956.

This work considers the measurement in flight of the boundary-yer characteristics of an untapered, untwisted, 45° sweptback lf wing of thin symmetrical section, mounted vertically on of the fuselage of an Anson Mark I aircraft.

The primary aim was to study the transition mechanism on eptback wings, and an account is presented of the experiments far performed with this object in view. Attention is also en to the design, development, and construction of a suit-e boundary-layer traversing gear.

For an incidence range of 0° to 10°, and Reynolds numbers of 4, 4½, 5, 6, 7, and 8 million, the static pressure distributions were determined and also the locations of transition for both surfaces using the creeping surface pitot technique.

For both upper and lower wing surfaces transition was found to move towards the leading edge with increase of either incidence or Reynolds number. This is in agreement with the results obtained by Butler. From authors' summary

1214. Belcher, G. L., Deflection measurements on a 45° swept and tapered rectangular tube, *Aero. Res. Labs., Melbourne, Austral. SM Rep.* no. 228, 11 pp. + 2 tables + 7 figs., June 1955.

As part of a program of stress and deflection analysis of swept tubes, a tube of rectangular cross section, tapered in both planform and thickness and having 45° of sweep at the leading edge, was loaded by a concentrated load at each of eight points in turn, and deflections were measured at eighteen positions for each load position.

A comparison was made between measured deflections and one method of predicting deflections. The predicted deflections at the outboard edge of the root triangle and those near the tip of the tube are of the order of 10% and 70%, respectively, of the measured deflections. From author's summary

1215. Sedney, R., Geometrical optics of angular stratified media, *Quart. appl. Math.* **14,** 3, 225–230, Oct. 1956.

Author attempts to simplify the interpretation of optical phenomena of light traversing angular stratified media. By application of a "similarity property" of the light paths some conclusions are drawn. The method is applied to the case of supersonic flow with the significant result that the refraction does not affect the validity of conical flow observations. Though paper has its merits, reviewer does not see that it helps greatly in reducing the work of interferometer test evaluation. H. Ramm, USA

Thermodynamics

(See also Revs. 996, 1096, 1170, 1203, 1247, 1248, 1249, 1252, 1255, 1258, 1264, 1269, 1270, 1271, 1272, 1273, 1280, 1282)

Book—1216. Coulson, J. M., and Richardson, J. F., Chemical engineering, 2nd ed., New York, McGraw-Hill Book Co., Inc.; London, Pergamon Press Ltd., 1955, vii + 384 pp. $7.50.

This excellent book starts with a discussion of units and dimensions and a short recapitulation of thermodynamical fundamentals, and the energy equation of fluid in motion. Already this part makes it clear that it is not a common book. Authors introduce in the entropy a measure of the degree of irreversibility and, at the flow, the difference in the bulk velocity and the root-mean-square velocity. The dynamics of flows in pipes and canals is treated in the following two chapters, where the problem of flow of compressible fluids in pipes at great pressure drop is of special interest. Different flow meters, including the orifice meter, the rotameter, are followed by a review of special pumps for chemical works. Here the use of compressed air for pumping is explained with good illustrations.

Section for heat transfer gives the modern view of this very important subject, but is very condensed. A special section is devoted to momentum, heat and mass transfer, where mass transfer is specially described in stationary gas. The similarity between momentum transfer, heat transfer, mass transfer, viscocity, thermal conductivity, diffusivity is explained, followed by a summary of what we know about the boundary layer. Here most of the formulas are deduced in the text. The last section treats humidification and water cooling.

Book ends with an appendix containing tables of physical properties, and unsolved problems, as well as problems in the different text sections, which are solved.

Reviewer finds the book also very good for mechanical

engineers, but has some objections. Authors say on page 3 that they shall use only mass, length, and time as the fundamental unit (expressed in lb, ft, and sec) and they derive the formulas in this manner. They use, however, in the examples not these units, nor from these units derived units, but use there, as in the tables in appendix, a conglomerate of units. It is certainly a good exercise for the students, but would it not be better to use everywhere the cgs units or the units in Georgie system with kg as mass, meter as length, i. e., "MKS"-system, now accepted in physics. On page 158, authors use the Laplace transform in solving unsteady transfer of heat. Is not this a bit advanced mathematically for a chemical engineer?

The general information on page 169 that streamline conditions are impractical is not correct. The new technic with very small dimensions very easily gives streamline in combination with high heat transfer. On pages 193–199, nothing is said concerning the very important problem of heat transfer to boiling liquids in horizontal pipes. On page 248, the expressions for u_m is incorrect. Mass transfer at streaming medium is too briefly treated in comparison with its importance.

Reviewer suggests the section for humidification and water cooling whould be thoroughly revised. The explanations with Fig. 10.6 on page 316 and the explanation of methods of increasing humidity with Fig. 10.10 are not satisfactory.

M. Backstrom, Sweden

Book—1217. Godnev, I. N., Determination of thermodynamic functions according to molecular data [Vychisleniye termodinamicheskikh funktsiĭ po molekulyarnym dannym], Moscow, Gos. Izdat. Tekh.-Teor. Lit., 1956, 419 pp. 13.50 rubles.

The elements of statistical thermodynamics and the application of related methods to the determination of thermodynamic functions of gases, liquids and partly also of solids are scattered in various textbooks on statistical physics, physical chemistry, statistical mechanics, etc. Based on the well-known fundamental relation between the free energy and the sum of the selected states of a quantomechanical system, the monograph under consideration brings, in contrast to what has been said above, a systematic presentation of the subject.

Being written for engineers, physicists, research workers, and students of physico-chemical faculties, the book is of a mathematical physical character. Its study presupposes adequate knowledge in the advanced calculus as well as in the elements of classical and quantum mechanics.

Subject is divided into 14 chapters, the last of which is devoted entirely to modern tables. Brief titles of separate sections will give a more detailed idea of matters involved: I. Fundamental formulas of statistical thermodynamics. II. Application of general formulas to the theory of ideal gases. III. Thermodynamic functions of one-atomic gases. IV. Energy levels and states of two-atomic molecules. V. Determination of thermodynamic functions of two-atomic gases. VI. Classification and symmetry of multiatomic molecules. VII. Rotation energy levels and vibrations of quasirigid molecules. VIII. Determination of thermodynamic functions of quasirigid molecules. IX. Thermodynamic functions of gases in the case of free rotation. X. Determination of thermodynamic functions of gases in the case of damped internal rotation. XI. Determination of thermodynamic functions of real gases, liquids, and solids with the aid of corresponding functions of ideal gases. XII. Calculation of chemical equilibria. XIII. Determination of equilibrium constants for reactions with isotopes. XIV. Tables.

Volume concludes with a detailed index of literature followed by a carefully made list of notations. External form is very nice, paper good, and print excellent. Presentation is clear and vivid; each more advanced fact of higher mathematics and quantum mechanics is explained by instructive comments and references to related literature sources. Book is highly recommended to interested specialists.

V. Vodicka, Czechoslovakia

1218. Popov, K., The mathematical foundations of the theory of irreversible thermodynamical processes, *Soviet Phys. (JETP)* **1,** 2, 336–353, Sept. 1955. (Consultants' Bur. Translation)

1219. Karanikolov, K., The phenomenological relations of Onsager, *Soviet Phys. (JETP)* **1,** 2, 265–267, Sept. 1955. (Consultants' Bur. Translation)

Book—1220. Haywood, R. W., edited by, Thermodynamic tables and other data, New York, Cambridge University Press, 1956, 23 pp. $0.50. (paperbound)

This booklet of 23 pages contains eight tables presenting thermodynamic properties of water, taken from the work of Keenan in 1941 and Keenan and Keyes in 1936. Water information concerning the volume, internal energy, entropy, and enthalpy of the saturated liquid and gas, the superheated gas, and the condensed liquid is presented for temperatures up to 1600 F. Tabular material is an abridgment of the basic information.

Thermodynamic properties of ammonia, carbon dioxide, Freon 12, and methyl chloride are reported for temperatures between −40 and 120 F. For the refrigerants there is recorded only information concerning the specific volume, enthalpy, and entropy for the saturated liquid and gas and superheated gas for 50 F and 100 F superheat.

B. H. Sage, USA

Book—1221. Vukalowitsch, M. P., and Elsner, N., Thermodynamic properties of water and water vapor [Thermodynamische Eigenschaften des Wassers und des Wasserdampfes], Berlin, VEB Verlag Technik, 1954, 94 pp. + 8 diagrams.

A translation into German was made of Professor M. P. Vukalovich's tables and charts which were originally printed in the U.S.S.R. in 1951. Slight changes in the foreword were made from the original material but tables and technical discussion are intact. Tables record values of volume, entropy, and enthalpy for the saturated liquid and gas to a maximum temperature of 705 F. Similar information is given for the condensed liquid and superheated gas at pressures up to 4000 psi for temperatures up to 1294 F. Heat capacities of the superheated gas under isobaric and isochoric conditions are presented at pressures up to 4250 psi. The viscosities and thermal conductivities of the saturated liquid and gas phases as well as the condensed liquid and superheated gas are included up to 1294 F and 4250 psi.

These data are based primarily on Russian measurements and are at some variance with recent American volumetric measurements. Thermodynamic consistency apparently was assured by the use of an equation of state to describe the volumetric behavior of the superheated gas. Some divergences still exist between American and Russian values of the transport properties.

B. H. Sage, USA

1222. Hirschfelder, J. O., Heat conductivity in polyatomic or electronically excited gases, *Univ. Wisc. Nav. Res. Lab., Dept. Chem. Rep.* WIS-ONR-18, 14 pp., Apr. 1956.

The usual Eucken equation for the heat conductivity of a molecule with internal degrees of freedom is derived and improved. In the improved form the correction to the coefficient of thermal conductivity for the internal degrees of freedom of the molecule is given by the factor $0.115 + 0.354\, C_p/R$. With the help of reference (1), author proves that this approximation is valid only if the electronic states are not metastable and if the coefficients of diffusion of all the molecular quantum states are equal. The metastable electronic species lead to anomalously large coefficients of thermal conductivity, whereas the usual excited electronic states, because of their gigantic size, give a much smaller contribution to the coefficient of thermal conductivity than would be expected on the basis of the Eucken assumption. It is postulated that the abnormally large heat conductivity of N_2O and CO_2 at temperatures above 500 C, may be due to the existence of metastable states.

From author's summary

1223. **Maizel', S. S., Universal *I-t* diagram for liquid fuels** (in ssian), *Teploenergetika* **3,** 1, 58–60, Jan. 1956.

1224. **Backstrom, M., Simple theory of the gas circulation in orption refrigerating units of the v. Platen-Munter system** (in rman), *Trans. roy. Inst. Technol. Stockholm* no. 101, 72 pp., 56.

By means of material and energy balances and using customary thods of computing concentrations or temperatures in heat changers and absorbers, the conditions of operation of an sorption-plus-evaporation type of refrigeration cycle are studied. cause of the similarity relations between heat and mass transfer efficients (apparently pointed out by the author in 1926), it is ssible to derive rather simple relations between the changes in monia partial pressure in the steps of a closed cycle involving ammonia-hydrogen system. No data are reported; this is a tailed process analysis, which, except for a few rather general nclusions, will require design data for complete use.

Three questions involving choice of optimum operating conditions the cycle which are studied are: (a) how fast should the gas eam circulate; (b) how should the available difference in liquid el in the evaporator and the absorber be subdivided between the w resistances in the evaporator, the heat exchanger, and the sorber; and (c) what is the optimum amount of cooling surface in absorber? With respect to (a), too fast a flow of inert gas duces such a large duty in the evaporator, owing to the sensible at extracted from the gas, that the refrigeration effect is reduced. e calculations show that the flow of inert gas should under some ditions be as much as 1.8 times the minimum quantity needed to nsport the volatile component, assuming saturation at the exit m the absorber and from the evaporator. With respect to (b), half nore of the total pressure drop should be used in the heat exnger employed for cooling the gas flowing to the evaporator by rmal contact with the gas returned to the absorber. With respect c), whether it is more desirable to add cooling surface or to absorption surface in the absorber depends on the other erating conditions. R. L. Pigford, USA

1225. **Mitoff, S. P., and Pask, J. A., A recording differential rmal expansion apparatus,** *Bull. Amer. ceram. Soc.* **35,** 10, 402–, Oct. 1956.

1226. **Tritsmans, P., Gas analysis by the mass spectrometer,** *ch. Wet. Tijdschr.* **25,** 8, 183–186, Aug. 1956.

rticle gives a description of the mass spectrometer and explains method of calculation of the gas-mixture analysis. Time-ciency, precision, maintenance, and staff requirements are also cussed. From author's summary

1227. **Alekseev, V. P., and Martynovskii, V. S., Vortex tempera--separation effect in superheated vapors and experimental test- of the Hilsch-Fulton hypothesis** (in Russian), *Izv. Akad. Nauk R Otd. Tekh. Nauk* no. 1, 71–79, Jan. 1956.

1228. **Martynovskii, V. S., and Alekseev, V. P., Thermodynamic lysis of the effect of gas and vapor separation in a vortex tube** Russian), *Teploenergetika* **2,** 11, 31–34, Nov. 1955.

1229. **Burkardt, L. A., McEwan, W. S., and Pitman, H. W., paratus for obtaining heating and cooling curves,** *Rev. sci. rum.* **27,** 9, 693–696, Sept. 1956.

he apparatus described here permits the study of phase diaams either by heating or cooling. One temperature control circuit mits a preset temperature gradient, either positive or negative, e maintained between the sample and bath with the temperature he bath being controlled by that of the sample. The appearance disappearance of solids in the sample is followed by measure- of the light transmission of the sample. A second control uit provides constant bath temperatures. A stepwise approach he liquidus point, with the light transmission used to indicate the establishment of equilibrium between solid and liquid at each step, offers a means of determining this point under equilibrium conditions. From authors' summary

1230. **Wilson, W. A., An analytic procedure for optimizing the selection of power plant components,** ASME Semiann. Meet., Cleveland, O., June 1956. Paper 56-SA-51, 21 pp.

Paper presents a systematic procedure for optimizing the selection of equipment necessary for a steam power plant. Author eliminates the cut and try procedures generally used for component selection by a method not previously considered. It should be of interest to those designing and selecting power-plant components for study and consideration, even though some may regard it as too technical or too complicated for their practical applications.
C. C. Eckles, USA

1231. **Tsien, H. S., Thermonuclear power plants,** *Jet Propulsion* **26,** 7(part 1), 559–564, 575, July 1956.

Some of the unique features of thermonuclear power plants and the essential problems in the technical design of such plants are discussed. The thermonuclear reaction rate for the fusion of deuterium is calculated on the basis of a similar analysis published by Gamow and Teller. The pressure, temperature, and minimum dimensions of the necessary reaction chamber are determined largely by consideration of reaction quenching and energy loss near the walls. Results are presented for the power output and the efficiency of a power station utilizing the deuterium fusion reaction. The comment by Greenstein that follows this paper deals particularly with the difficult problem of calculating the reaction quenching and energy loss rates at the walls.
From author's summary

1232. **Krebs, R. P., and Miller, W. S., Jr., Performance analysis of fixed- and free-turbine helicopter engines,** *NACA TN* 3654, 49 pp., June 1956.

An analysis of fixed- and free-turbine engines applicable to helicopter propulsion was made at the NACA Lewis Laboratory. Generalized performance charts are presented for these engines; and comparisons are made of off-design specific fuel consumption, altitude performance, power-speed characteristics, and response times. Calculations are made for the flight performance of an assumed 30,000-pound helicopter powered by the fixed- and free-turbine engines.

Components for the fixed- and free-turbine engines are so chosen that the design-point specific power outputs and fuel consumptions are identical.

Variations in free-turbine power with changes in shaft speed (constant turbine-inlet temperature) were small. The fixed-turbine engine, on the other hand, showed significant reduction in power with decreased shaft speed at constant temperature.

Variations in compressor-inlet temperature had nearly identical effects on the power outputs of the two engines. Power modulation of the fixed-turbine engine at constant shaft speed was very rapid, while the response speed of the free-turbine engine was limited by the accelerating characteristics of the gas-generator component. Simultaneous changes in speed and power were executed by the fixed- and free-turbine engines in about the same time.

No significant differences in range or hovering time were found for the fixed- and free-turbine helicopters. Range and hovering time for both were slightly improved when operational tip speeds were reduced from 650 to 550 fps). At a tip speed of 550 fps, the free-turbine helicopter gave slightly improved rate of climb over that obtained at 650 fps, primarily because of the flat power-speed characteristic of the engine and the improved aerodynamics of the rotor. In contrast, the rate of climb for the fixed-turbine helicopter was greatly reduced when the tip speed was decreased from 650 to 550 fps. From authors' summary

1233. Varley, J. H. C., The thermal expansion of pure metals and the possibility of negative coefficients of volume expansion, *Proc. roy. Soc. Lond.* (*A*) **237,** 1210, 413-421, Nov. 1956.

Paper gives theoretical considerations on the thermal expansion α of metals. It is shown that there are two contributions to α, one from the entropy due to the lattice vibrations—always leading to positive α—and one from the entropy due to the valence electrons. The latter contribution may lead to negative α provided the density of states of the electrons changes rapidly near the Fermi energy and provided there are a large number of overlapping energy bands at the Fermi energy. These conditions will probably occur in heavy transition metals, and it is suggested that the observed negative α in plutonium (and uranium) could be explained in this way. D. ter Haar, England

Heat and Mass Transfer

(See also Revs. 1216, 1222, 1224, 1225, 1227, 1228, 1231, 1269, 1270, 1271, 1272, 1273, 1296)

Book—1234. Hurst, R., and McLain, S., editors, Technology and engineering (Progress in nuclear energy, Ser. IV) **Vol. 1,** New York, McGraw-Hill Book Co., Inc.; London, Pergamon Press Ltd., 1956, xiii + 420 pp. $12.

The editors have assembled an excellent compendium consisting of selected articles covering technological aspects of coolants and moderators, heat transfer, and chemical problems resulting from intense radiation within the reactor. The individual sections, written by acknowledged authorities, present to the engineer the present state of technical knowledge. Part one covers articles on heavy-water, graphite beryllia, and liquid metals.

The early part of the text takes up the technological problems of coolants and moderators. A survey of heavy-water production processes and the final concentration of heavy water by rectification is presented. Under graphite, the areas of the production and properties of graphite for reactors and the production of nuclear graphite in France are set forth. The subjects of the production of pure beryllium oxide, the sintering of beryllium oxide, and the technology of manufacturing items of pure beryllium oxide for use in nuclear reactors are covered in the section on beryllia. Under liquid metals one finds the subjects of liquid-metal handling and sodium and sodium-potassium alloy for reactor cooling adequately handled.

The second part of the text, entitled Engineering, includes the following subjects: pumping of liquid metals, mechanical pumps for power-reactor cooling systems, boiling heat transfer, heat transfer by compound gas in the Saclay Pile, heat transfer by smolten metals, liquid-metal heat transfer, liquid-metal heat-transfer predictions, the possibility of improving the heat transfer between uranium and aluminum surfaces in contact, and thermal strains and deformations in the rod and canning of a heterogeneous high flux reactor.

The third portion of the text covers phases of reactor chemistry and erosion. In this section one finds the following articles by recognized authorities: the radiolytic behavior of water in a nuclear reactor, pressurized water reactor water chemistry, a survey of homogeneous reactor chemical problems, aqueous uranium and thorium slurries, the corrosion of aluminum, aqueous corrosion of zirconium and its alloys at elevated temperatures, corrosion by liquid metals, and metallurgical studies on liquid bismuth and bismuth alloys for reactor fuels and coolants.

One particular advantage of this volume is that it contains articles by authors from many countries. This text constitutes a contribution toward the benefit of mankind since it will tend to extend the science and technology of the peaceful use of nuclear energy.

The book should be of real value to engineers and scientists in academic and industrial areas interested in the subject, as it presents an over-all picture of the present state of nuclear knowledge. G. A. Hawkins, USA

1235. Reiniger, F., The study of thermal conductivity proble by means of the electrolytic tank, *Philips tech. Rev.* **18,** 2, 52- 1956/57.

Electrolytic-tank analog study of thermal behavior of the ano of an x-ray therapy tube is effected. Anode comprises block of copper with a small thin plate of tungsten on front of it where energy absorption takes place; other side of anode is cooled wi oil which conducts heat away. Details of temperature distributi are studied: in the anode, in relation to thickness of copper blo over the surface in contact with the cooling liquid; and in relati to size of the tungsten focal plate.

Account of theory underlying construction of analog model an of details of its construction are followed by numerous plots of data so obtained. An appendix encompasses mathematical basis of analogic investigation. This paper is of especial interest in treatment of possible temperature discontinuities in the thermal field. T. J. Higgins, US

1236. Fedorov, V. I., Shvets, I. T., and Shel'menko, N. N., I vestigation of temperature distribution in several types of turbi rotors in the nonsteady heat-transfer regime (in Russian), *Teplo energetika* **2,** 11, 27-31, Nov. 1955.

Paper describes experimental method for measuring temperatu distributions, as a function of position and time, in turbine roto The method is based on rather obvious and well-known similari considerations. Under very restrictive assumptions, experiment which simulate fast starting or shut-down of turbines can be per formed on small, nonrotating models. The weakness of the meth lies in the fact that the influence of blades is disregarded, and that the coefficients of heat transfer between rotor and working fluid are assumed known. With the assumptions included in the paper, it is probably easier and more economical to obtain the solution by numerical methods with the aid of a high-speed com ter. The authors' claim of a 2% accuracy (should read—repro-ducibility) of measurement is rather meaningless in view of the highly idealized scheme adopted for the models.

J. Kestin, US

1237. Levy, S., Heat-conduction methods in forced-convectio flow, *Trans. ASME* **78,** 8, 1627-1635, Nov. 1956.

Paper deals with a theoretical treatment of forced convection flow between parallel plates, circular conduits and annuli, by in tegrating the energy equation, using a combination of analytical and finite-difference technique. The flow cross section is sub-divided into a series of parallel laminae or concentric cylinders depending upon the flow configuration and, as such, the method applicable to any arbitrary velocity and diffusivity distributions However, both these distributions are independent of the distan measured from the entrance along the direction of the main flow. The energy equation considered is in its simplified form and is completely analogous to the one-dimensional heat equation. Co sequently, the method of solution closely follows that due to Jaeger in dealing with conduction of heat in composite slabs.

Numerical results are presented for flow between parallel pla with constant wall flux, linear wall temperature variation, and c stant wall temperature at one surface with either constant flux zero temperature at the other. Good agreement is obtained with Martinelli and Seban's data. Expressions of thermal entrance length are given for fluids of large Prandtl number for the case constant wall temperature and constant wall flux. These expre sions predict an increase of entrance length with increasing Prandtl number and a decrease with increasing Reynolds numbe Such prediction is not in full agreement with results of Deissle and Berry. B. T. Chao, US

1238. Young, R. L., Heat transfer from a rotating plate, *Tra ASME* **78,** 6, 1163-1168, Aug. 1956.

Paper presents results of an experimental investigation of he transfer to air from a horizontal circular plate rotating at spee

m 0 to 500 rpm with Δt's from 10 to 60 F. Above 250 rpm (rotional Reynolds number of 500), data are correlated by

$$Nu = 0.56\,(Re\,Pr)^{0.40}$$

uthor's results are somewhat higher in this range than those pre-cted by Wagner [*J. appl. Phys.* **19**, 837–839, 1948]. Below 250 m, natural convection is seen to play an important role, and data e correlated by a rather complicated expression involving Δt as ll as Re.

Reviewer believes experiments were carefully performed and pro-de a useful contribution to the heat-transfer field, and hopes, ong with one of paper's discussors (Florence F. Buckland, neral Electric Company, Schenectady), that further studies can performed with a vertically mounted plate. Reviewer also hopes at further studies can be made in the future to help understand enomena occurring in natural convection region.

R. L. Mela, USA

1239. Backstrom, M., Connection between heat convection and essure drop (in Swedish), *Kyltekn. Tidskr.* **15**, 3, 31–33, June 56.

1240. Beckers, H. L., Heat transfer in turbulent tube flow, *Appl. Res. (A)* **6**, 2/3, 147–190, 1956.

The temperature field and heat transfer for turbulent flow through ube is calculated by an integration of the differential equation $r)\,\partial/\partial r\,[r(a + A_q)(\partial T/\partial r)] = v(\partial T/\partial z)$ (r radius, a thermal diffusivity, A_q turbulent diffusivity, T temperature, v velocity, xial direction) for the condition of hydraulically developed flow d tube wall cooled on the outside to a constant ambient tempera-e beginning at $z = 0$. (Numerical calculations are restricted to nstant wall temperature.) Integration was performed separately laminar sublayer, buffer layer, and turbulent core and integra-n constants were determined so that a smooth temperature pro-e resulted. This profile is described by a linear combination of genfunctions. The first two eigenvalues and eigenfunctions are ulated for $P_r = 0.1$, 1, 10, 100 and several Re values between 10 d 3×10^6. From these results, Nusselt numbers for thermally tablished flow and in the entrance region and thermal entrance gth are determined and presented in figures and tables. In-esting is the result that a considerable variation of entrance gth with Prandtl number may be observed. Agreement with asurements by J. Hartnett is good.

E. R. G. Eckert, USA

1241. Chapman, D. R., A theoretical analysis of heat transfer in ions of separated flow, *NACA TN* 3792, 47 pp., Oct. 1956.

Author gives an analytical treatment of a flow field between a parated viscous mixing layer and a solid surface for laminar parations. The differential equations are solved for arbitrary ch number.

Results are presented in tabular form for Prandtl numbers be-en 0.1 and 10.0. The rate of heat transfer to a separated lami-r region in air ($Pr = 0.72$) is calculated to be 0.56 of that to a responding attached laminar boundary layer having the same nstant pressure. Injection of gas into the separated region is culated to have a powerful effect in reducing the rate of heat nsfer to the wall.

Application to turbulent separations await detailed measurements velocity profiles in turbulent boundary layers.

M. A. Mayers, USA

1242. Siegel, R., and Norris, R. H., Tests of free convection in artially enclosed space between two heated vertical plates, ME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-5, p.

The free-convection heat-transfer coefficients were measured, as unction of spacing, for two parallel, electrically heated, vertical tes. The top of the rectangular space between the plates was open, and during most of the tests the bottom and sides were sed. The heat input per unit area was substantially uniform, and the Grashof number, based on plate height, was of the order of 10^{10}. The results demonstrate how the surface-temperature rise increases, or the local Nusselt number decreases, as either of the cross-section dimensions of the free-convection space is reduced. This decrease in Nusselt number is less rapid than was expected from purely two-dimensional flow considerations. This is ascribed to the effect of an asymmetrical flow pattern observed in the space. In some cases, a periodic reversal of this asymmetrical flow also was observed. When the space between plates was opened sufficiently at the bottom, the results were reasonably consistent with the correlation proposed by Jakob for a single vertical plate with a turbulent boundary layer; these results were almost independent of spacing between the heated surfaces down to the minimum spacing tested.

J. R. Stalder, USA

1243. Fischer, J., and Dosch, F. P., Heat transfer by free convection from electrically heated thin wires to air (in German), *Z. angew. Phys.* **8**, 6, 292–297, June 1956.

The over-all heat-transmission coefficient was determined in a series of very accurate tests using platinum wires with a diameter from 0.11 down to 0.02 mm and a temperature difference of up to 600 C.

The results are presented as graphs of the form: $Nu = F(Gr\,Pr)$ and compared to other similar research work. Authors claim that the condition of genuine free convection is seldom realized.

M. Rand, Canada

1244. Kollman, F., and Malmquist, L., Investigation of radiation behavior of drying wood (in German), *Sven. Träforsklnst. Medd.* 73-B, 9 pp., 1955.

1245. Gardon, R., The emissivity of transparent materials, *J. Amer. ceram. Soc.* **39**, 8, 278–287, Aug. 1956.

The emission of thermal radiation by diathermanous materials is reviewed from first principles and is compared with the more familiar emission of radiation by opaque surfaces. The work is particularly directed toward radiation phenomena in glass at high temperatures, but also leads to some valuable concepts regarding the emission of radiation by both diathermanous and opaque bodies in general. An expression for the volume emissive power is derived, and it is shown that the radiant flux within a diathermanous radiator exceeds the radiation emitted into the air by a factor approximately equal to the square of the refractive index.

The spectral emissivities of isothermal diathermanous sheets are expressed in terms of their optical properties and of their thickness. The results are illustrated by a discussion of the total hemispherical emissivities of sheets of window glass at various temperatures. The commonly accepted value of 0.91 is shown to be the same for all glasses having a refractive index of 1.5, but that it applies only for sheets above a certain minimum thickness. For window glass, this ranges from 3/16 in. at 200 C to 8 in. at 1000 C. At 1000 C, a 3/16-in. sheet has an emissivity of only 0.59. Finally, the application of the results to calculations of the radiative cooling of diathermanous sheets is briefly indicated.

The paper is a valuable reference for glass technologists and students of radiation alike.

A. Whillier, South Africa

1246. Ranz, W. E., On the evaporation of a drop of volatile liquid in high-temperature surroundings, *Trans. ASME* **78**, 5, 909–913, July 1956.

Evaporation rate is calculated making the following assumptions: (1) Heat transfer is by conduction, radiation, and mass transfer, but not by convection; (2) all heat reaching drop surface is absorbed by latent heat of vaporization; (3) drop surface temperature is constant and can be estimated either from wet-bulb temperatures or from boiling-point temperatures; and (4) concentrations and temperatures in gas phase do not change with time. Results, obtained as solutions to heat-transfer equation, emphasize that heat transfer to drop surface is reduced appreciably by mass transfer. Results are not compared with experimental data.

Reviewer suggests that the drop surface temperature could be calculated with only little additional work by solving simultaneously the equations for heat transfer and for mass transfer. The mass-transfer equation is entirely similar to the heat-transfer equation in this case, and the solution to one equation is essentially the solution to the other equation. The drop surface temperature is very nearly the saturation temperature corresponding to the vapor pressure at the drop surface. [See AMR **9**, Rev. 1267.]

E. L. Knuth, USA

1247. Itoo, K., and Hama, K., Freezing of supercooled water-droplets, Part I, *Pap. Meteor. Geophys.* **6,** 3/4, 247–254, Jan. 1956.

An experiment was conducted in which a water droplet was frozen to find the effects of artificial rain-making. Taking a distilled water drop, a drop of silver iodide suspension in pure water, and, further, a rain drop, their freezing temperature was observed. As the variance of the temperature was great in each case, some improvement was found necessary for practical use.

From authors' summary

1248. Hill, T. I., Surface diffusion and thermal transpiration in fine tubes and pores, *J. chem. Phys.* **25,** 4, 730–735, Oct. 1956.

The role of surface transport in the passage of a gas at low pressure through fine tubes or pores is examined in terms of simple models of mobile and localized adsorption. The amount of surface transport becomes about equal to the amount of gas transport when the tubes or pores have radii of the order of several hundred Angstrom units. The theory predicts that surface transport will have little effect on the pressure gradient across the tube or pores in the absence of a temperature gradient. But the pressure gradient should be increased considerably, as a result of surface transport, over the usual (thermal transpiration) pressure gradient when there is a temperature gradient across the tube or pores.

From author's summary by R. M. Drake, Jr., USA

1249. Kondo, S., Thermodynamical fundamental equation for spherical interface, *J. chem. Phys.* **25,** 4, 662–669, Oct. 1956.

Author derives the fundamental equation for interface and investigates the relation between the position of the Gibbs dividing surface with the superficial density and the "surface tension" by purely thermodynamical means. The surface of tension is defined as that particular dividing surface making the "surface tension" stationary, which later proved to be the minimum. Expressions of the superficial densities are given. Surface tension is then related to the *tangential* stress on the dividing surface. This stress is found to reach a large negative value at the interface. Reviewer feels that the sign of tangential stress needs clarification, contrary to the convention concerning normal stress.

Although author emphasizes the difference between change of curvature and of position of the interface, the restriction to spherical interface eliminates any differences.

L. S. Dzung, Switzerland

1250. Kafarov, V. V., The theoretical analysis of diffusion processes, *J. appl. Chem. USSR* **29,** 1, 43–48, Jan. 1956. (Consultants' Bur. Translation)

A critical review and discussion of the existing diffusion theories are presented. Author then formulates a generalized theory in which mass transfer is considered to take place via molecular and eddy processes simultaneously. The fundamental equation describing the rate of mass transfer is

$$q = -(D + E_g)C_x$$

wherein q is the rate of mass transfer, D the molecular diffusivity (independent of hydrodynamic conditions), E_g the eddy diffusivity, and C_x the concentration gradient. The evaluation of E_g must be empirical. The theory gives rise to several familiar dimensionless groups: Nusselt, Prandtl, Peclet, and Reynolds numbers. In these groups the eddy diffusivities of mass and momentum are used. The theory is applicable to the regime of molecular transport, mixed molecular and eddy transport, eddy transport predominating, and eddy transport accompanied by interfacial breakdown (emulsification). A group involving surface tension for prediction of emulsification conditions is not presented. Although there is reference to evidence of quantitative support of the theory, no data are presented.

M. Baker, USA

1251. Lauwerier, H. A., Diffusion from a point source into a space bounded by an impenetrable plane, *Appl. sci. Res. (A)* **6,** 2/3, 197–204, 1956.

An exact and simple solution of this diffusion problem is given by a superposition of point source (or, alternatively, elementary) solutions. It can be used for determining the concentration of particles of a metal evaporated between two electrodes.

P. Kriezis, Greece

1252. Proceedings of the colloquium on diffusion (in French), **Montpellier, June 1955;** *Publ. Sci. Tech. Min. Air, France,* NT 59, 95 pp., 1956.

In this colloquium, nine papers were presented on the following subjects (contributors' names are added in brackets): Fundamental concepts in diffusion (J. Salvinien). Statistical theory of diffusion (J. J. Moreau). Numerical evaluation of diffusion experiments (P. Vernotte). Diffusion in membranes (R. Marignan). Interferometric methods for observing diffusion in liquids (E. Calvet & H. Patin). Tracer methods in diffusion experiments (S. Cordier). Diffusion with simultaneous precipitation in gels (J. Salvinien). Applications of diffusion in the chemistry of proteins (M. Kaminsky; P. Grabar).

The papers on experimental and numerical methods and some of the applications are of interest for laboratory work in which diffusion is involved, intentionally or unintentionally. The theoretical contributions are of little originality and do not take account of known facts of nonlinear diffusion.

R. Eisenschitz, England

1253. Shitsman, S. E., Preventing corrosion in air preheaters (in Russian), *Teploenergetika* **3,** 2, 37–40, Feb. 1956.

1254. Hammer, W., Thermal ratings of buildings can be uniformly compared, *Heat. Pip. Air Condit.* **28,** 9, 88–91, Sept. 1956.

1255. Gurvich, A. M., and Kuznetsuv, N. V., Changes in and additions to norms for the thermal calculation of boiler units (in Russian), *Teploenergetika* **3,** 1, p. 60, Jan. 1956.

1256. Kazakevich, F. P., and Cherednichenko, A. V., Heat exchange and aerodynamic resistance in cross-baffled banks of tubes (in Russian), *Teploenergetika* **2,** 11, 35–37, Nov. 1955.

1257. Scharf, W., Problems of nuclear energy (in Polish), *Przegl. tech.* **76,** 4, 131–134, Apr. 1955.

Paper is a brief description of the problems connected with utilizing atomic energy for electric light, heating, etc.

M. Z. Krzywoblocki, USA

1258. Glawe, G. E., Simmons, F. S., and Stickney, T. M., Radiation and recovery corrections and time constants of several chromel-alumel thermocouple probes in high-temperature, high-velocity gas streams, *NACA TN* 3766, 25 pp., Oct. 1956.

Report gives the radiation and recovery corrections as well as the time constants for 9 chromel-alumel temperature probes. The environment ranges covered were Mach number from 0.3 to 0.9; static pressures from 2/3 to 4/3 atm; and temperatures from 1500 to 2500 R for radiation, and time constants and recovery data were obtained for Mach numbers between 0.2 and 0.9, pressures from 4/3 to 5/3 atm, and at room temperature. Not only are tables and graphs presented but detailed sketches of the thermocouples used are available for comparison purposes.

E. E. Sechler, USA

259. Iliukhin, N. V., **Temperature measurement in a high-city gas stream** (in Russian), *Teploenergetika* **3**, 2, 20–25, 1956.

Combustion

(See also Revs. 1223, 1252, 1253, 1255, 1276, 1281, 1293)

260. Grumer, J., Harris, M. E., and Rowe, V. R., **Yellow-ing of bunsen burner flames and related exchangeability of s in gas utility systems,** *Indust. Engng. Chem.* **48**, 11, 2052–, Nov. 1956.

aper is one of a series of studies on flashback, blow-off, and ow tipping properties of gaseous fuels and the influence of gas liances that utilize them. It presents theoretical considera-s and data summarizing the limiting conditions under which gas-er flames are yellow. The yellow tip limit is defined as the -air composition of the stream within the port for which yellow st perceptible in the flame above the port.

he information presented, according to the authors, makes it sible to predict the yellowing or non-yellowing of flames for fuels on single port burners in free air at room temperature pressure.

urther research is expected to relate the new body of infor-on to the performance of present-day gas appliances.

onstant yellow tip limits have been obtained as a limiting e for increasing port diameter and flow. The influences of shapes, depths, and temperatures have been explored.

R. Delbourgo, France

261. Wright, F. H., and Beckler, J. L., **Combustion in the ng zone between two parallel streams,** *Jet Propulsion* **26**, 11, -978, Nov. 1956.

abilization of flames by bluff bodies plays an important role aintaining combustion in jet propulsion units. Experiments gned to simulate this stabilization phenomenon used coaxial llel gas streams, one being hot and the other being of com-ible mixture. Combustibles studied were acetylene, propane, on disulphide, and a light petroleum hydrocarbon. Turbulent ng conditions were employed.

nition of combustible by the hot stream was only possible e a certain hot-stream temperature. This temperature de-ed on fuel type and was related to fuel activation energy. achment of flame from initial point of mixing varied with erature of hot stream but was essentially independent of ure ratio or stream speeds.

moderate air speeds and fuel-air ratio a further flame ap-ed downstream, propagating into cool combustible mixture. achment of this flame from initial point of mixing varied with -air ratio and with stream speed. The propagating flame was blished only when residence time of combustible material in ng zone (governed by physical factors) was long enough to to ignition of mass of gas adequate to serve as secondary ion source (governed by chemical factors).

M. F. Hoare, England

262. Chu, B.-T., **Mechanism of generation of pressure waves lame fronts,** *NACA TN* 3683, 20 pp., Oct. 1956.

ressure waves are known to be generated at a flame front when-there is a change in the flame speed or the heating value or sity of a combustible mixture. It is shown that if the specific-ratios of the burned and unburned gases are the same, the sure waves generated at the flame front are really caused by a ge in the rate of heat release at the flame. In the matter of eration of pressure waves, therefore, a flame behaves es-ially like a heater. The performance of a flame and a heater en compared and the conditions under which the two are amically equivalent are stated.

From author's summary by A. A. Putnam, USA

1263. Weiss, M. A., and Longwell, J. P., **Low pressure performance of cylindrical can burners,** *Jet Propulsion* **26**, 9, 749–756, Sept. 1956.

A study was made of the combustion stability and combustion efficiency of cylindrical can burners, 2- to 5-in. diam, at low pressure ($\frac{1}{6}$ to $\frac{1}{2}$ atm abs). Cans with one, two, and three stages of inlet holes were tested and stability was found to depend primarily on the geometry of the upstream (first) stage of holes and the region inside the can (the recirculation zone) upstream of that stage. Size and location of downstream stages were of minor importance to stability but did affect over-all efficiency. Tests were conducted to determine the effects of varying the number and size of first-stage inlet openings, and the diameter and length of the recirculation zone. The effects of changing pressure, mass flow, inlet jet direction, recirculation zone wall temperature, and tailpipe length were also studied. In an empirical stability correlation, the lean and rich blowout limits are functions of the superficial first-stage velocity divided by the product of can diameter and pressure to the 0.8 power. A can stability mechanism depending on over-all reaction rates in a local zone is suggested.

From authors' summary by D. M. Simon, USA

1264. Mickelsen, W. R., and Baldwin, L. V., Aerodynamic mixing downstream from line source of heat in high-intensity sound field, *NACA TN* 3760, 75 pp., Aug. 1956.

The processes of fuel-air preparation, combustion, and exhaust-gas mixing in jet-engine combustors depend to a large degree on aerodynamic mixing. Since combustors commonly have intense sound fields, it is of interest to investigate the effect of sound on the fundamental mixing process. This report describes a theoretical and experimental investigation of the aerodynamic mixing by a standing sound wave downstream from a continuous line source of heat.

By a kinematic analysis of the motion of the molecular-diffusion wake, equations are derived for the time variation of temperature and the time-mean temperature at points throughout the mixing region. The analysis shows that standing sound waves displace the diffusion wake in a manner similar to the displacements of a flag waving in a harmonic mode. The diffusion-wake displacement has nodal points downstream from the line source at distances which are integer multiples of the ratio (*stream velocity*)/(*sound-wave frequency*). The maximum wake displacement occurs at the antinodal distances and is equal to ($\sqrt{2}$ × *rms transverse velocity fluctuation*)/ (π × *sound-wave frequency*). The theoretical analysis considers two general cases: (a) small and (b) large geometrical deformations of the diffusion wake by the transverse sound waves. The analysis shows that the deformations are characterized by stretching of the wake and by the relative magnitudes of the wake radius of curvature and thickness. The stretching is greater for high sound intensities. The curvature is greater for high sound intensities and high sound frequencies. When the wake suffers negligible deformation, the sound field contributes to the mixing in the time-mean sense; but the instantaneous, or local spatial, structure of the temperature field is unaffected. For the case of appreciable wake deformation, the temperature field is substantially changed in both the time-mean and instantaneous senses.

From authors' summary

1265. Waler, P. L., Jr., Correlation of equilibrium atom and free radical concentrations in flames of carbon monoxide, hydrocarbon and air with burning velocities and flame stabilities, *Fuel* **35**, 2, 146–152, Apr. 1956.

Author points out that the Tanford-Pease hydrogen-ion concentration theory of burning velocity inadequately correlates data for mixtures of carbon monoxide, propane or methane, and air when low concentrations of propane or methane are used. Author suggests, but rejects, possibility of accounting for the discrepencies on the basis of incorrectly computed equilibria, erroneous rate constants, or the ignoring of chain-branching reactions.

E. S. Starkman, USA

1266. Pekker, Ya. L., and Belodvortsev, A. A., Abrasion by entrained particles of anthracite culm (in Russian), *Teploenergetika* **3**, 1, 46–49, Jan. 1956.

1267. Friedman, R., and Cyphers, J. A., On the burning rate of carbon monoxide, *J. chem. Phys.* **25**, 3, 448–457, Sept. 1956.

Burning velocity measurements of the $CO—O_2—N_2—H_2O$ system were made with the flat-flame burner technique. The plan of experimentation was to vary the H_2O content, the equivalence ratio, and the pressure, while holding the flame temperature constant by controlling the proportion of N_2 in the mixture. The results could be represented empirically by the relation:

$$v_u^2 = 3.8 \times 10^6 (CO)_u (H_2O)_u^{0.5} (P/P_{atmos})^{-0.24} e^{-11\,130/T_b}$$

where v_u is burning velocity (cm/sec), $(CO)_u$ and $(H_2O)_u$ mole fractions in the unburned gas, P pressure, and T_b burned-gas temperature. The Zeldovich, Frank-Kamenetsky, and Semenov equation was used to obtain an "over-all" activation energy (20 kcal) and frequency factor for the process, and the CO oxidation rate in this type of flame was then compared with the rate at which the CO forming as an intermediate in a lean hydrocarbon-air flame is oxidized in the downstream portion of such a flame. The comparison showed that, at comparable conditions, the CO oxidized 5.6 times as fast in the CO flame as in the hydrocarbon flame. Temperature traverses in hydrocarbon-air flames to which large proportions of H_2O have been added show the rate of CO oxidation to be slightly increased thereby.

Equilibrium concentrations of the species H, OH, and O in the burned gases were calculated for a variety of $CO—O_2—N_2—H_2O$ mixtures, all at the same flame temperature, and correlations with burning velocity were sought. The square of the burning velocity was found to be directly proportional to $(OH)_b(CO)_b^{0.72}$; alternatively, the group $(H)_b(O_2)_b^{0.136}$ gave equally good correlation. A third successful grouping was $[(H)_b + 0.15(OH)_b]^{1/2}$. The writers are not convinced that correlations of this type reveal the burning mechanism. From authors' summary

1268. Brusin, M. A., Rates of surface ignition and combustion in an anthracite bed (in Russian), *Teploenergetika* **3**, 1, 41–46, Jan. 1956.

The papers from the five sessions of the Joint Conference on Combustion were published in 1955 as preprints of the Institute of Mechanical Engineers (Great Britain) and the American Society of Mechanical Engineers. A bound volume will be published in 1957. The papers are reviewed by sections I, II, III, IV, V.

1269. SECTION I, General. 31 pp.

The following four papers are included in the General Section.

Edgerton, A., The chemistry and physics of combustion. Part I, Chemical aspects of combustion. Author states that he reviews basic combustion phenomena rather than specialized aspects pertinent to particular applications. He points out, correctly, that both the chemistry and the physics of a combustion reaction must be considered, but his paper is concerned primarily with the chemistry of combustion. Although up-to-date references are cited, the most promising modern theories and viewpoints are slighted. This paper should help bring the uninitiated up to date on problems which have necessitated the modern approach to combustion research, namely the study of aerothermochemistry. To the scientist conversant with the subject, the paper constitutes a concise summary of information usually found in scattered sources.

Saunders, O. A., and Spalding, D. B., The chemistry and physics of combustion. Part II, Chemical and physical factors controlling the rate of combustion. Authors discuss how both chemical and physical factors come into play in controlling the rate of combustion; however, at times one or the other predominates. This paper includes much interesting work and the well-known orig approach of one of the authors is quite evident.

Lewis, B., and von Elbe, G., Scientific principles combustion and their application.

Sherman, R. A., and Reid, W. T., An appraisal of c bustion research. A. B. Cambel, U

1270. SECTION II, Boilers, 70 pp.

Nine authors contribute papers to this section devo to boilers.

Stevens, W. D., Instruments as applied to detection flame failure. Types of flame dectector and their fiel application to multiple-burner oil- and gas-fired boiler are discussed.

Campbell, O. F., Some methods of disposal and eli nation of petroleum refinery waste gases. Two types CO furnaces (with supporting fuel supply) and waste h boiler and one type of waste-gas eliminator furnace (n boiler, no monetary return) are described.

de Lorenzi, O., Furnaces for low-quality solid fuels Layout and results of pulverized-fuel furnaces burning lignite, high-sulfur, medium-ash bituminous coal and c spreader stoker installations are discussed. They off no operating difficulties for extended periods.

Burdick, L. R., and Corey, R. C., Effect of fuel pro ties on firing method. American practice is discussed Gas- and oil-burner selection is based on considerati other than fuel properties. Coal-burning equipment is selected according to rank, caking characteristics, be havior of ash and slag, size consistency.

Crossley, H. E., and Marskell, W. G., Boiler availa bility: A commentary. The findings of the boiler-avail bility committee are summarized; fused-slag, high-tem ture deposits are discussed and conclusions drawn. T need for caution in the interpretation of investigations and close cooperation is stressed.

Frazer, R. P., Liquid-fuel firing. Authors present a thorough survey of (1) atomization, especially twin-flu atomizers), (2) combustion, (3) utilization of heat, and control.

Simonson, W. F., Combustion of pulverized fuel for steam generation. The development is sketched by a comparison of a typical 1929 plant and a 1951 plant; a tation to special cases and unusual fuels (brown coal, peat) is discussed.

Seidl, H., The development and practice of cyclone firing in Germany. High ash-retention and cleaner flu gas make cyclone firing attractive. Lines of develop are tangential firing, finer pulverizing, increased tem ture, mixing or additions according to slag characteris tics. Applications to boilers in operation and under c struction (Sept. 1954) and experiences are cited.

Platt, N., Spreader stokers and combustion. The re sults of the first British installation (Kearsley, 1949) during four years of operation and the modification ma (additional overfire-air jets, type of grate bar, etc.) a discussed in great detail. Results are encouraging. W. Gumz, Germa

1271. SECTION III. Industrial furnaces. 70 pp.

Ten papers cover the various aspects of industrial furnaces.

Funk, E. J., Gas as a source of protective atmosph in industrial furnaces. Paper describes types of gas, endothermic (made by catalytic reaction and external ing) or exothermic (made by gasification or combustio followed by cleaning). Nature of gas is characterized the equilibrium constant of the water-gas shift reactio

Turin, J. J., and Huebler, F., The status of combus

industrial furnaces. The major problem is the transfer of the heat produced to the work in an automatic controllable positive manner.

Percy, J. W., Instruments as applied to product improvement in steel furnaces. Mekler, L. A., Instrumentation of process tubular heaters. The papers by Percy and Mekler both outline the important role of instrumentation and automatic control as exemplified by the steel industry and in oil heaters.

Henwood, J. B., High-temperature gaseous jets as applied to some manufacturing processes. An internal-combustion nozzle with controlled temperature and exit velocity and a radiant burner of Selas Corp. are described, and typical applications to various processes shown.

Pearson, S. W., Chesters, J. H., and Thring, M. W., Combustion and heat transfer in the open-hearth furnace. A quantitative theory is being developed for predicting the effect of changes in furnace design and operation, based on measurements taken during a single heat. The calculations indicate that radiation accounts for virtually the whole of the heat transfer and that this mathematical model applies satisfactorily.

McInerney, M. J., Mattocks, G. R., and Newby, M. P., Oil burners for open-hearth furnaces. Investigation of the optimal shape of the burner to produce jet momentum as economically as possible, which can be achieved by rather simple shapes. The use of twin burners, spaced as far apart as practical, is suggested.

Jungbluth, H., and Roesch, K., Advances in cupola combustion. An empirical relation of melting capacity is developed as a function of blast quantity, coke charge, blast temperature, and oxygen content. Various types of hot-blast furnaces and heaters are described.

Jack, H. R. S., Kruszewski, S., and Richardson, D. A., Combustion and heat transfer in glass tanks. Referring to producer-gas heated tanks, factors affecting combustion and heat transfer are studied by model techniques and calculations; heat-transfer theories in glass are reviewed. Many problems require more investigation. Improved gas quality (preheated blast, O_2 enrichment) is suggested, but the possibility of entirely new designs must not be overlooked.

Southern, H., Gray, F. A., and Smith, D., Combustion and thermal transfer in continuous reheating furnaces. Various theories and methods of calculation are reviewed, and experimental furnace results are discussed showing the need for further data on the mechanism of heat transfer from recirculated gases. W. Gumz, Germany

SECTION IV. Internal combustion engines. 89 pp.

Eight authorities contribute papers on recent advance in basic combustion problems as applied to internal combustion engines.

Kauffmann, W. M., High-compression turbocharged spark-ignition gas. Paper is a comprehensive review of latest progress in improving two- and four-stroke cycle supercharged SI engines. Latest experience with gaseous fuels in turbocharging of port-scavenged two-cycle engines is discussed. Knock is apparently still a primary restraining phenomenon.

Longwell, J. P., and Weiss, M. A., Heat release rates in hydrocarbon combustion. In this extension and review of homogeneous fuel-air reactor operation and analysis authors relate blow-out limits to reaction rate theory, previously suggested by Longwell, and empirically establish the chemical kinetic constants applicable.

Livengood, J. C., Toong, T. Y., Rona, T. P., Taylor, C. F., and Black, I. A., Surface ignition in a motored engine. Paper relates heat transfer in boundary layer to ignition phenomena in engines with an acceptable degree of reliability. Semi-empirical relationships are used for correlations.

Lyn, W. T., Combustion products and wear in high-speed compression-ignition engines, with particular reference to the use of lower grade fuels. Resume of recent progress on abrasive and corrosive reciprocating engine wear phenomena includes bench test results and extensive analysis of deposit composition.

Jackson, P., Combustion in large diesel engines. Author discusses the fuel combustion problems arising from various characteristics of the world's crude oils. Specifically, it deals with problems arising in large diesel engines capable of operating on residuals. Included are important characteristics of the residuals from the world's major oil sources.

Davies, S. J. (Introduction), Hoffmann, Heinz (Part I), Lang, H. (Part II), Cordier, O. (Part III), Combustion in diesel engines with divided combustion chambers Part I: Combustion in pre-combustion-chamber engines; Part II: The Lanova combustion process, a brief description of its development and function; Part III: Design notes on swirl chamber engines. Critical comparisons of the structure and performance of the various important types of diesel engine combustion systems are given. Authors utilize performance mapping for relating designs. Combustion processes resulting from various divided chamber configurations are described.

Vichnievsky, R., Combustion in petrol engines. Modified Mallard and Le Chatelier approach to flame speed is applied to analysis of gasoline-engine combustion phenomena. Paper compares knock performance of various fuels to composition.

Moore, N. P. W., and Mitchell, R. W. S., Combustion in dual-fuel engines. Engine-associated phenomena using gaseous fuels is related to various information in the literature on other performance criteria, such as flame speed, ignitibility, etc. Authors present analysis of properties of a number of pure and mixed gaseous fuels.

E. S. Starkman, USA

1273. SECTION V. Gas turbines. 76 pp.

The final session of the conference was devoted to ten papers which discuss gas turbines.

Karlovitz, B., Application of electronic probes to measurements in turbulent flames. Author described electronic probes for measuring ionization in flame fronts and thereby identifying their positions and fluctuations.

Droms, C. R., and Dahl, A. I., Iridium versus iridium-rhodium thermocouples for gas temperature measurement up to 3500 F. This paper reports the development and calibration of iridium versus iridium-rhodium thermocouples for use up to 3500 F.

Hazard, H. R., Coal-firing for the open-cycle gas turbine—a comparison of methods. Author compares pulverized coal, spreader stoker, cyclone and producer gas methods of coal firing. He estimates last two methods have lowest likely dust to turbine and effect on cycle efficiency.

Hershey, A. E., Combustion of blast-furnace gas in gas turbines. This paper on the successful development of burners for blast furnace gas presents evidence of the superiority of turbulent-diffusion type of combustors over types in which air and fuel are premixed.

Clarke, J. S., The relation of specific heat release to pressure drop in aero-gas turbine combustion. Some diagrams are presented showing the flow in the primary zones of combustion chambers and author outlines the results of calculations of fuel spray evaporation in a practical combustion system.

Tipler, W., Combustion chambers and the control of

temperature at which they operate. Here the problem of flame tube wall temperature in industrial gas turbines burning residual fuels is dealt with. The cooling of plane and louvered walls is discussed. Author concludes that refractory walls offer greatest advantages.

Hurley, T. F., and Battock, W. V., The use of solid fuels in gas turbines. Authors give a full summary of results obtained by various contractors and research establishments in the work on solid fuel combustion sponsored by the Ministry of Fuel and Power. Work on straight through, vortex, and cyclone combustion chambers, slagging producers and gas cleaning equipment together with experience on turbine blade deposits is included.

Kind, C., Operating experience with combustion equipment in industrial gas turbines. This paper reports some of Brown Boveri's experiences in the development and operation of liquid and gas-fired combustion chambers.

Sulzer, P. T., and Bowen, I. G., Combustion of residual fuel in gas turbines. Authors describe experience with doped and undoped fuel oils on the Weinfelden (20,000 KW semiclosed cycle stationary) and Auris (open-cycle separate power turbine, marine) plants. In both plants, the use of an aluminum-silicate additive reduced deposition. In the Auris plant, ash deposition was decreased as stack smoke increased. Shut down caused spalling of blade deposits. Magnesium was found ineffective in reducing deposition. Corrosion in the Weinfelden air-heater was effectively overcome by additives. Authors also compare laboratory tests with operating experience.

Probert, R. P., Application of research to gas-turbine combustion problems. Paper is a survey of the progress in research into atomization, fuel-air mixing, and droplet evaporation and burning. Author discusses the problem of applying research results in combustion chamber design. Experiments on scale effects show importance of maintaining correct relation between momentum of fuel and airstreams. W. R. Hawthorne, England

Acoustics

(See also Revs. 1097, 1264)

1274. Pridmore-Brown, D. C., and Ingard, U., Tentative method for calculation of the sound field about a source over ground considering diffraction and scattering into shadow zones, *NACA TN* 3779, 33 pp., Sept. 1956.

Based on theory and some measurements, a rough estimate is made of the amounts of sound energy diffracted and scattered into the acoustic shadow region in a linear wind gradient. Diffraction estimates are based on Blokhintzev's wave equation for a moving medium. Scattering estimates are based on Lighthill's theory for sound scattering by atmospheric turbulence. Several plots and contour charts show calculated sound pressure fields for various source heights, distances, frequencies, and wind velocities. W. Soroka, USA

1275. Fay, R. D., Successful method of attack on plane progressive finite waves, *J. acoust. Soc. Amer.* **28,** 5, 910–914, Sept. 1956.

Reviewer believes that there is some confusion in establishing the equation of continuity. Author considers the front end of an elementary volume to move with the velocity of energy propagation, while the near end moves with the mass velocity of the medium. The result is an equation which is neither an equation of conservation of mass density nor of energy density. Reviewer therefore doubts the significance of the results obtained in this paper. J. M. Jackson, Scotland

1276. Dubinika, E. F., and Kudriavtsev, B. B., Speed of sound propagation in mixtures of chemically reacting substances (in Russian), *Zh. fiz. Khim.* **29,**4, 677–681, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 7 pp.)

1277. Homoto, O., Theory of ultrasonic absorption in aqueous solutions I. Introduction and general theory, *J. phys. Soc. Jap.* **11,** 8, 827–840, Aug. 1956.

Water has been characterized as having a broken-down ice structure (i.e., as an ice-water mixture). The origin of the anomalous absorption of ultrasonics in water has been attributed by Hall [*Phys. Rev.* **73,** 7, 775–780, Apr. 1948] to a lag in the rearrangement of molecules between the associated state (ice) and the closer packed single state (liquid) which fails to follow the acoustic pressure cycle. Author extends this concept to explain the additional ultrasonic absorption in aqueous solutions by proposing a "diffusion relaxation mechanism." Thus when the excess pressure in the sound wave melts some of the associations of water molecules (ice), molecules of the solute must diffuse from the surrounding solution into the fresh water thereby created. This process accompanies a change in configurational entropy, the entropy increasing in the compressed volume element. This entropy increase is approximately reversible, becoming perfectly reversible in the quasi-stationary limit. This reversible increase in entropy ΔS, however, requires a heat quantity $T\Delta S$ (T absolute temperature), which must be supplied by the volume element itself. Thus the specific heat apparently increases by an amount C_m, which corresponds to the specific heat of the internal degrees of freedom of the molecules in the case of the molecular absorption of sound. The general formula for the anomalous ultrasonic absorption in aqueous solutions has been obtained along these lines and under appropriate assumptions.

J. L. Stewart,

1278. Hikata, A., Truell, R., Granato, A., Chick, B., and Lucke, K., Sensitivity of ultrasonic attenuation and velocity changes to plastic deformation and recovery in aluminum, *J. appl. Phys.* **27,** 4, 396–404, Apr. 1956.

Measurements of changes in ultrasonic attenuation together with changes in ultrasonic velocity have been made concurrently with load strain measurements in tensile tests on the same specimen of aluminum. The results of such measurements taken during loading of the specimen, during relaxation or recovery at constant strain, and during unloading show a number of interesting effects. These observed effects are interpreted in terms of dislocation behavior for the various stages of the experiment. The experimental results for attenuation α and velocity change $\Delta v/v$ permit the calculation of changes in dislocation density and loop length based on a dislocation damping theory developed to include both megacycle and kilocycle frequencies. The strain due to dislocation motion was calculated with a simple model and with dislocation loop lengths and densities obtained from the data and the theory just mentioned. Comparison of the calculated strain and the measured strain lends support to the use of this model, and, while this dislocation damping model may not be entirely correct, it does seem possible to obtain information about stress-strain behavior at low strains from sound propagation data alone. From authors' summ

1279. Seki, H., Granato, A., and Truell, R., Diffraction effects in the ultrasonic field of a piston source and their importance in the accurate measurement of attenuation, *J. acoust. Soc. Amer.* **28,** 2, 230–238, Mar. 1956.

A study is made of the ultrasonic field produced by a circular quartz crystal transducer and the integrated response of a quartz crystal receiver with the same dimensions as the transducer. Transducer and receiver are taken to be coaxial, and it is assumed that transducer behaves as a piston source while the

egrated response is proportional to the average pressure over receiver area. Computations are made for cases of interest the megacycle frequency range (ka = 50 to 1000; a piston dius; λ wave length; $k = 2\pi/\lambda$). Results contain features of in identifying and correcting for diffraction errors. These tures, which apparently have been missed in previous in-tigations, are compared with available experimental data. ally, correction formulas to account for diffraction effects he accurate measurement of attenuation are discussed. It shown that the order of magnitude of the diffraction attenua- is given by one decibel per a^2/λ.

From authors' summary

1280. Krishnamurthi, M., **Transmission of ultrasonics through ary liquid mixtures,** *Proc. Indian Acad. Sci.* (*A*) **43,** 2, 106–112, b, 1956.

Ultrasonic velocities and absorption in five binary liquid mix-es have been studied in relation to their concentration. They benzene-ethylene dichloride, ethyl alcohol-oleic acid, diozane-yl methyl ketone, benzyl alcohol-ethyl alcohol, and benzyl ohol-isopropyl alcohol. The rapid increase in absorption of zene with the addition of small quantities of ethylene di-oride, the negligible influence of small quantities of ethyl ohol on the high absorption of oleic acid, the sharp peak in orption-concentration curve in the case of ethyl methyl ketone-xane mixtures, the sharp minima in the last two mixtures are tained qualitatively. From author's summary

Ballistics, Detonics (Explosions)

(See also Rev. 988)

1281. Morgan, M. S., Silverman, J., and Webber, W. T., **The oretical specific thrust of a rocket motor for the C-H-N-O-F ystem,** *Jet Propulsion* **26,** 10(part 1), 874–877, 891, Oct. 1956.

Statement of problem: To reduce time necessary to compute oretical specific thrust.

Description of method: For a chamber pressure of 500 psia; pressure 14.7 psia, thrust is computed for 21 species of actants reducible to system C-H-O-N-F. The work was done a digital computer using 5 variables: the weight ratios C/ + H), O/(O + F), %N, an "oxidation ratio" defined as gram ms of O and/or F in the mixture to required stoichiometric, an "effective heat of formation" defined as heat required to vert reactants at entrance temperature to their elements at 16 K, standard state. Calculations were based upon adia-ic combustion, equilibrium composition of combustion products ozen at chamber conditions, isentropic expansion and optimum expansion ratio at sea level. The results are in the form of phs of specific impulse as a function of the variables cited ve.

Statement of important results: One interesting graph shows the ssible effects of nitrogen substitution for C in an unsaturated drocarbon. In the use of such a chart author claims a skilled rator can determine specific thrust in 1/2 hour as opposed to estimated 35 to 50 hours using desk calculator.

Reviewer considers this a worthwhile contribution to the litera-e of rockets and looks forward to projected performance manual which paper is to be a part. Authors' statement on accuracy of sults apparently refers to desk calculator versus digital com-er; reviewer doubts whether component data would justify the s or minus 1% claimed for the results. J. H. Potter, USA

1282. Epstein, L. I., **The design of cylindrical propellant ins,** *Jet Propulsion* **26,** 9, 757–759, Sept. 1956.

ch rockets one wants a thrust which is a given function of . For given choices of rocket motor and propellant, this implies that burning surface area of propellant grain is a given function of the distance into grain which is burned through. Author shows how to design as internally burning propellant grain in order to comply with this demand.

A. Silfverhielm, Sweden

1283. Probulski, K., **Kazimierz Siemienowicz, Polish pioneer in rocket technique** (in Polish), *Tech. Lotnicza* **11,** 3 (33), 66–73, May-June 1956.

Paper gives an account of rockets constructed and described in works of Siemienowicz in 17th century.

M. Z. Krzywoblocki, USA

Soil Mechanics, Seepage

Book—1284. Craemer, H., **Soil statics (Statika La),** Beograd, Gradjevinska Knjiga, 1952, 160 pp.

Author deals first (49 pages) with strength and strain characteristics of soils, in the following 45 pages with stresses and strains in the half space, and in the final 66 pages with the stability of retaining walls (56 pp.), of slopes (5 pp.), and of footings (5 pp.). Classic methods are treated only, and some original comments are given. However, those concerning the stresses in half space due to a couple of forces (p. 65) and the bearing capacity of square footings (p. 160), are not acceptable. No account is taken of the latest development in soil mechanics. Of 44 references only one book has been published after 1944 and German authors only are cited, except for Coulomb and Rankine. L. Suklje, Yugoslavia

1285. Nisle, R. G., **The effect of a short term shut-in on a subsequent pressure build-up test on an oil well,** *J. Petr. Technol.* **8,** 8, 67–68 (Technical Note), Aug. 1956.

In conducting a pressure build-up test on an oil well, it is often necessary to shut-in the well for a short time prior to initiation of the test. The effect of such a short-term shut-in on the resulting pressure build-up curve is derived. The derivation is based on the Kelvin point-source solution and is a straightforward extension of the fundamental theory.

The magnitude of the effect is evaluated and illustrated by an example. It is shown that if the production subsequent to the short-term shut-in is at least 10 times the duration of the shut-in, the effect will be less than 10%.

From author's summary

1286. Rorabaugh, M. I., **Ground water in northeastern Louisville, Kentucky, with reference to induced infiltration,** U. S. Geol. Surv. Water Sup. Pap. 1360b, 101–169, 1956.

Results of a fifteen-day aquifer-performance test accomplished on the bank of the Ohio River are presented and analyzed. Methods of determining permeability, effective distance to line of recharge, storage coefficient, etc., are given. Effects of temperature variation and stage of river are treated mathematically very effectively. Deviations between observations and theoretical expectations are discussed and evaluated in terms of the difference between assumed and actual hydrogeological conditions.

Reviewer believes that this paper contains a unique study, one that has not been made (at least, not published) by anyone else: the temperature distribution, and changes in temperature, which occur throughout a large section of aquifer as water pumped by a well is replaced by river water of different temperature which has infiltrated to the water-bearing formation. Two cross sections of aquifer are presented for each of twelve different dates, showing observed isotemps. Changes in temperature distribution reflect flow of water infiltrating from river, stratification, differences in permeability, etc. Based on this test there is a step-by-step analysis showing how to compute the quantity of water available from the aquifer at Louisville from a

well field containing any given number and type of wells.
R. G. Kazmann, USA

1287. Petersen, J. S., Rohwer, C., and Albertson, M. L., Effect of well screens on flow into wells, *Trans. Amer. Soc. civ. Engrs.* **120,** 563-607, 1955.

The hydraulics of wells involves flow (1) in the surrounding aquifer, (2) through the well screen, and (3) inside the well. This paper is concerned with the flow through the screen and inside the well. A theoretical development is presented which relates the loss of head to the characteristics of the well screen. To support the theoretical development, a laboratory investigation of well screens was made.

The objective of the investigation was to establish criteria which could be used to aid in the selection of well screens to meet the varied conditions found throughout the United States. To do this, screen coefficients (permitting the use of a theoretical equation for design purposes) were determined for specific well screens. From authors' summary

Micromeritics

(See also Revs. 1285, 1286, 1287)

1288. Maybank, J., Fenrick, W. J., and Cuthbertson, K. J., A magnetically stabilized spinning disk apparatus for homogeneous aerosol production, *Defence Research Board, Canada* Pap. no. 105, 4 pp., Oct. 1956.

A spinning disk apparatus which produces nearly homogeneous aerosols is described. The disc is stabilized by eddy currents set up in it by an electromagnet. The braking action of the magnet makes it possible to operate the disc at low speeds, and use driving air at a pressure sufficiently high for removing the satellite droplets. The droplet diameter of the liquid aerosol produced can be varied from 10 to 200 microns, the coefficient of variation of the diameter of a given aerosol being approximately 3 to 5 per cent. The liquid feed rate may be varied from 0.5 to 2.0 cu cm per min. The apparatus is fully described, showing the outside appearance, a sectioned drawing, and the electromagnet circuit. Samples of photographs of droplets, using dibutyl phthalate liquid are shown having remarkable uniformity; the diameters vary from 30 to 270 microns depending on the angular velocity of the disc.
K. J. DeJuhasz, USA

1289. Pilcher, J. M., Approaches to aerosol problems, *Battelle Tech. Rev.* **5,** 4, 3-8, 1956.

The rapid expansion of aerosol applications is creating a growing need for more knowledge of their nature and potentialities. General definition of aerosols covers their properties, production, characteristics, particle-size determination. Cascade Impactor developed at Battelle Memorial Institute is described. Author points out the use of aerosols in the chemical industry, the growing size of aerosol production, and widening range of their application. He considers the problems of commercial aerosols; packaging, safety, development of satisfactory release valves, use of suitable propellant gases. K. J. DeJuhasz, USA

1290. Kynch, G. J., The effective viscosity of suspensions of spherical particles, *Proc. roy. Soc. Lond.* (*A*) **237,** 1208, 90-116, Sept. 1956.

Paper presents a mathematical analysis based on the equations of motion for an incompressible fluid with inertia terms neglected. This yields an expression for concentration dependence which agrees with Einstein's first-order correction and Vand's [*J. coll. phys. Chem.* **52,** p. 277] second-order correction; moreover, with a correction for close-packing effects, expression closely approximates data for solids concentrations as high as 25% by volume.

Reviewer believes analysis is of value, but feels organization and discussion could be improved. For example, repeated references to the electric analog are inserted without distinguishing clearly whether the electric or hydrodynamic problem is being considered; at times, this gives the erroneous impression that the problem involves the hydrodynamics of charged particles. Fortunately, enough discussion is included to permit the reader to work out the proper result, but considerable reader effort is required.
R. R. Hughes, USA

1291. DallaValle, J. M., Coagulation and sedimentation, *Proc. Amer. Soc. civ. Engrs.* **82,** HY 4 (*J. Hydr. Div.*), Pap. 1052, 11 pp., Aug. 1956.

Author presents a detailed summary of the present theory af coagulation based upon the treatment of Smoluchowski. Neglecting gravity and assuming an initially monodisperse system of particles equations are developed giving the number of single particles, double particles, etc., present in a suspension as a function of time. Present theories of free and hindered settling are also discussed. G. C. Wallick, USA

1292. Barthel, F., The static flow resistance and porosity of common porous building materials (in German), *Acustica* **6,** 2, 259-265, 1956.

The static flow resistance and porosity of common porous building materials are measured. The flow resistance in some cases rises very steeply with air velocity, a result not found for the measured sound-absorbing materials with fine pores. By comparing the measured resistance with acoustic resistance, deduced from measurements of wall impedances in a tube, one gets good agreement for absorbent materials with fine pores, but in samples of brick acoustic flow resistance is larger than static flow resistance and rises beyond a sound pressure level of 100 dB with air velocity. Values of "structure factor" up to 10 are found for the brick samples. From author's summary

1293. Jones, W. M., The flow of air through beds of charcoal, *Brit. J. appl. Phys.* **7,** 10, 370-373, Oct. 1956.

It is shown experimentally that the flow of air through beds of irregular porous granules of charcoal may be correlated with that through beds of solid spheres by using the usual equations for flow through granular beds. The envelope specific volumes of the charcoal granules are found with mercury after impregnating the granules with paraffin wax, and the envelope specific surface areas of the granules are deduced from measurements of the projected area and shape of the granules, according to the procedure laid down by Heywood. From author's summary

Geophysics, Meteorology, Oceanography

(See also Revs. 1080, 1247)

1294. Housner, G. W., Earthquake resistant design based on dynamic properties of earthquakes, *J. Amer. Concr. Inst.* **28,** 1, 85-98, July 1956.

Author presents a design method for determination of resistance of tall chimneys subjected to earthquake ground movement. Ground motion equation is taken from a previous paper by author. Computations of bending moments and shears are a little more sophisticated than those usually based on a percent *g* load assumption. Method gives estimates of bending moments and shears, making some allowance for influence of mass, height, radius, wall thickness, and variation of radius and thickness over the height. Paper is solely for practical purposes and there is no advance of general theory of response of structures to dynamic loads. W. H. Hoppmann, II, USA

1295. Doodson, A. T., Tides and storm surges in a long uniform gulf, *Proc. roy. Soc. Lond.* (*A*) **237,** 1210, 325-343, Nov. 1956.

By means of numerical integrations of the pertinent differential uations, the nonlinear interaction between tides and surges in long uniform gulf is estimated. W. H. Munk, USA

1296. Benton, G. S., and Dominitz, J., Measuring evapotranspiration from atmospheric data, *Proc. Amer. Soc. civ. Engrs.* HY4, (*J. Hydr. Div.*), Pap. 1035, 27 pp., Aug. 1956.

A method of evaluating evapotranspiration is presented which based on the mass balance of water vapor in the atmosphere. e method is applied to various regions of the North American ntinent for the calendar year 1949 and the results are compared h hydrologic data and with an empirical method of estimating apotranspiration.

t is shown that although accurate values of evapotranspiration n be obtained for large areas such as the entire continent, the curacy of the method is reduced as the size of the area under nsideration is decreased. The potentialities and limitations of proposed method are evaluated.

From authors' summary

Lubrication; Bearings; Wear

1297. Constantinescu, V. N., On the theory of gas bearings (in ench), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1,** 1, 1-155, 1956.

Analytical expressions are obtained, and corresponding curves e plotted, for the operating characteristics of gas-lubricated full rnal bearings of infinite length. A development of Harrison's proximate analysis is used [*Trans. Camb. phil. Soc.* **22,** 3, 39, 1913], the bearing being considered as equivalent to a pair identical inclined pad bearings in succession, the first being nvergent and the second divergent. Satisfactory agreement is und with experimental results due to Scheinberg [*Izd. Akad. uk SSSR* 8, 1953]. From the results derived it is possible to termine theoretically optimum running conditions for such a aring. The notation and operating parameters will be unfamiliar most English readers, but the results can be fairly readily nsposed. G. D. S. MacLellan, England

1298. Calikowski, R., Analysis of working conditions of ball-nned bearings used in aircraft instruments (in Polish), *Tech. otnicza* **10,** 2, 52-56, Mar.-Apr. 1956.

This is a calculation of pressure, moments, etc., in ball-pinned arings used in aircraft instruments, based upon Russian and Ger-n sources. M. Z. Kzywoblocki, USA

The following five papers, reviews 1299-1303, appeared in Proc. stn. Mech. Engrs. **169,** 36, 679-766, *1955.*

1299. Kettleborough, C. F., An electrolytic tank investigation into stepped thrust-bearings, pp. 679-688.

1300. Shawki, C. S. A., and Freeman, P., Journal bearing performance under sinusoidally alternating and fluctuating loads, pp. 689-698.

1301. Barwell, F. T., and Hughes, M. J., Some further tests on high-speed ball-bearings, pp. 699-716.

1302. Fogg, A., and Webber, J. S., The influence of some design factors on the characteristics of ball-bearings and roller-bearings at high speeds, pp. 716-745.

1303. Kettleborough, C. F., Michell bearing lubrication, Part I. Experimental results: Part II. Correlation between theory and experiment, pp. 746-766.

This brochure includes outstanding papers by well-known thors. Original contributions are presented for all categories. Due to volume of original data given by the several authors, injustice would only be incurred if specific comments were offered.

This compilation is of immediate interest to aircraft, automotive and bearing industries. F. Macks, USA

Marine Engineering Problems

(See Rev. 1017)

1304. Van Manen, J. D., and Sentic, A., Contra-rotating propellers, *Trans. Instn. nav. Arch. Lond.* **98,** 3, 327-345, July 1956.

After a brief description of the velocity field induced by a propeller, the results obtained from open-water tests with systematically varied contra-rotating propellers of the B3-65 type are discussed.

The results of these experiments are given in a $B_p - \delta$ diagram. With the aid of this diagram it is possible to derive a satisfactory survey of the efficiencies of contra-rotating propeller systems. This diagram also supplies data concerning the optimum diameters and the pitch ratios of the front and rear propellers.

An analysis, with the aid of circulation theory, of the results of the experiments shows that with a distance of 0.37 D between front and rear propellers the axial induced velocity generated by the rear propeller is, in way of the front propeller, about 20% of the value it has infinitely far downstream of the rear propeller.

Finally, a method based on circulation theory is developed by which contra-rotating propellers can be rapidly designed, provided they are of optimum diameter. From authors' summary

1305. Isay, W.-H., Calculation of the flow through a Voith-Schneider propeller (in German), *Ing.-Arch.* **24,** 3, 148-170, 1956.

A continuation of a previous article [W.-H. Isay, *Ing.-Arch.* **23,** p. 379, 1955] which is a necessary introduction to the present one. New material is a more accurate discussion of the effects of the free vortexes shed on the flow field at high advance ratios. Detailed computations are given for forces, moments, and propeller blade settings for strictly forward thrust. A critical discussion of previous calculations on the velocity field of free vortexes is given; it is pointed out that in the present case an important factor is that the propeller must move through the vortex field. Finally, a discussion of 4-bladed propellers is given and compared with the 6-bladed propeller discussed earlier.

B. W. Augenstein, USA

1306. Hughes, G., Viscous and interference effects deduced from N.S.M.B. and N.P.L. Victory model tests, *Trans. Instn. nav. Arch. Lond.* **98,** 3, 251-295, July 1956.

The Victory Ship model tests carried out at the Netherlands Ship Model Basin have been supplemented by a series of similar tests at the National Physical Laboratory. The combined results have been analyzed in relation to assumed viscous formulations, and the tank boundary interference effects required to provide a balance have been deduced.

It is shown that the interference effects which correspond to the viscous formulation proposed by the author from earlier work are consistent and reasonable, but further work of a similar kind is required to enable the viscous and interference effects to be separated out more accurately. From author's summary

1307. Jaeger, H. E., The determination of the scantlings of plates loaded by water-pressure or subjected to the combined action of water-pressure and compressive forces in their middle plane, *Inter. Shipbldg. Progr.* **3,** 23, 349-366, July 1956.

Contents of paper have appeared also in *Bulletin technique du Bureau Veritas*, Feb. 1954, and in *Schip en Werf* Oct. 22, 1954.

Author gives curves according to Timoshenko and to Schade for deflection and stresses in unstiffened and stiffened rectangular

...ates subjected to uniformly distributed load. Curves are commented on briefly. Limits to theory of plates are discussed.

When lateral load is combined with compressive forces in plane of plate, utilization of curves and of a magnification factor according to Bleich is described. Reviewer finds that use of a reduced magnification factor when deflection exceeds half plate thickness is restricted to simply supported plates and not, as author states, to plates with clamped edges. The mistake is evident and appea... also by comparison with Bleich's work [AMR **5**, Rev. 1037], from... which author has taken some part of the material.

Some remarks concerning influence of water pressure upon cri... cal (buckling) stresses are also given. A useful paper.

E. Steneroth, Sweden

Books Received for Review

BACHA, C. P., SCHWALJE, J. L., AND DEL MASTRO, A. J., Elements of engineering materials, New York, Harper & Brothers, 1957, xiii + 494 pp. $6.50.

BEER, F. P., AND JOHNSTON, E. R., JR., Mechanics for engineers. Statics and dynamics, New York, McGraw-Hill Book Co., Inc., 1957, xxv + 673 pp. $8.00.

BENESOVSKY, F., edited by, Plansee Proceedings 1955. Sintered high-temperature and corrosion-resistant materials, New York, Pergamon Press Ltd., 1955, viii + 472 pp. $11.00.

BISHOP, R. E. D., AND JOHNSON, D. C., Vibration analysis tables, New York, Cambridge University Press, 1957, viii + 59 pp. $2.00 (paperbound).

CESCOTTI, R., Luftfahrt-Definitionen, Band 4, München, Hanns Reich Verlag, 1956, 270 pp.

DEGARMO, E. P., Materials and processes in manufacturing, New York, The Macmillan Co., 1957, x + 755 pp. $8.50.

ELCOCK, E. W., Order-disorder phenomena, New York, John Wiley and Sons, Inc.; London, Methuen and Co., Ltd., 1956, ix + 166 pp. $2.50.

HAMMOND, R., Engineering structural failures, New York, Philosophical Library, Inc., 1956, 224 pp. $12.00.

JAEGER, J. C., Elasticity, fracture and flow (with engineering and geological applications), New York, John Wiley & Sons, Inc.; London, Methuen & Co., Ltd., 1956, viii + 152 pp.

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(Continued on outside back cover)

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